Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-75

Jill D. Lin

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Jill D. Lin
Vehicle Engineering/Mechanical System Division/ET-SRB Branch,
Kennedy Space Center, Florida

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DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS OF SHUTTLE MISSION STS-75

22 February 1996

Contributions By:

NASA, Lockheed-Martin, Rockwell, and Thiokol Members of the Debris/Ice/TPS and Photographic Analysis Teams

Prepared By:

Jill D. Lin
Shuttle Ice/Debris Systems
NASA/KSC/TV-MSD-7

Approved:

James G. Tatum
Chief, ET/SRB Mech/TPS Systems
NASA/KSC/TV-MSD-7

Gregory N. Katnik
Shuttle Ice/Debris Systems
NASA/KSC/TV-MSD-7

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

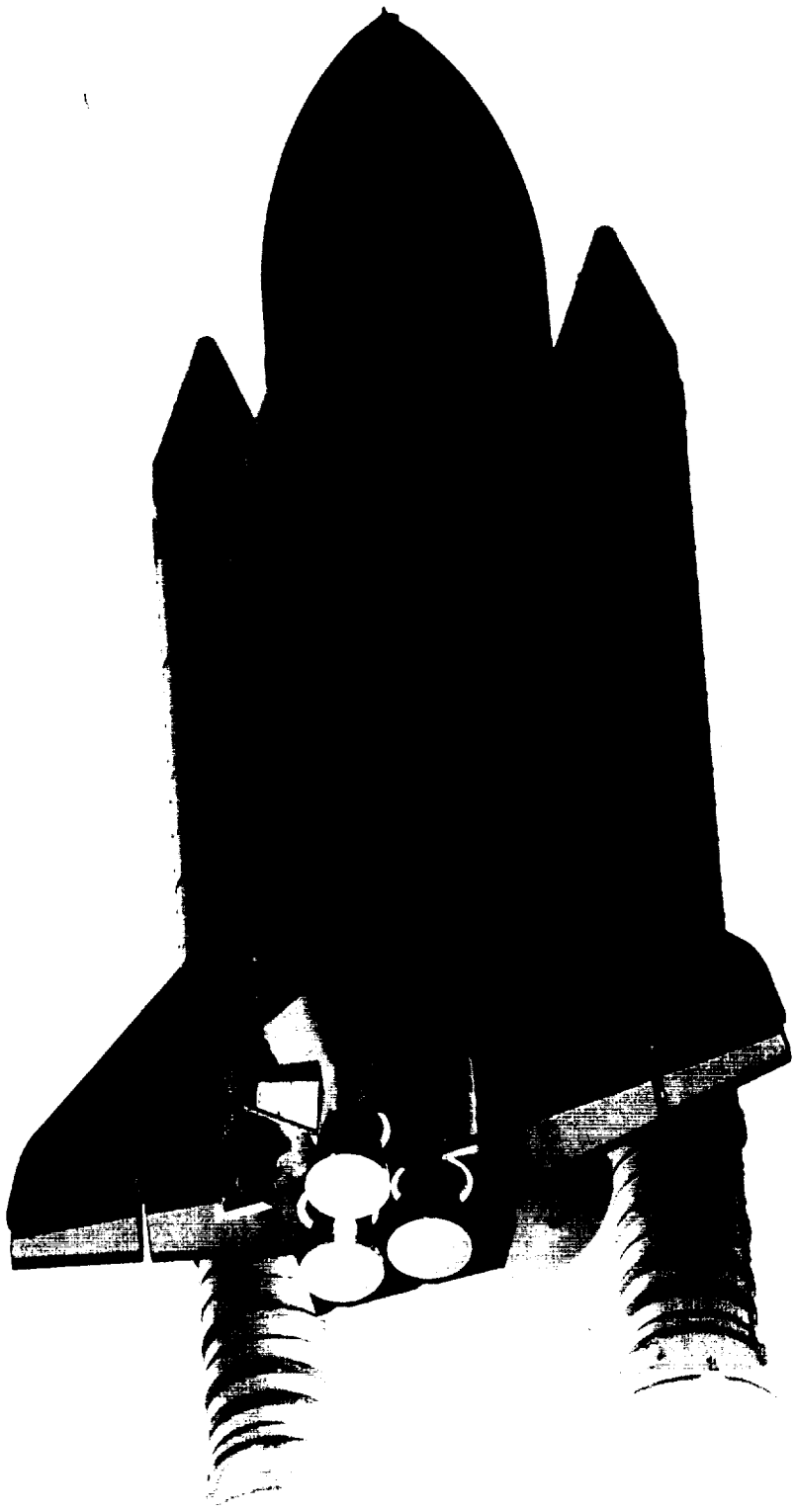


Photo 1: Launch of Shuttle Mission STS-75

1.0 SUMMARY

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 21 February 1996. The detailed walkdown of Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (19th flight), ET-76 (LWT 69), and BI-078 SRB's. There were no significant vehicle or pad anomalies.

The vehicle was cryoloaded for flight on 22 February 1996. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. No acreage icing or frost conditions were expected due to the mid-afternoon launch time. There were no ice/frost conditions or protuberance icing conditions outside of the established data base.

After the 3:18 p.m. (local) launch on 22 February 1996, a debris walk down of Pad 39B was performed. No flight hardware or TPS materials were found. Rockwell-Downey reported a 0.20g lateral acceleration at liftoff. Holddown post #5 stud hole exhibited burrs around the +Z edge, a visual indication of a stud hang-up. All the T-0 umbilicals operated properly. Overall, damage to the launch pad was minimal.

A total of 129 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission. SSME ignition appeared normal.

A stud hang-up occurred on holddown post #5. As the vehicle gained altitude and the LH aft skirt cleared the stud, a semi-circular piece of aluminum from the stud hole wall fell onto the southwest corner of the HDP shoe and then downward into the haunch area. Two fragments that may have been aluminum shavings fell from the stud hole area. No stud hang-ups occurred on any of the other holddown posts. No ordnance fragments or frangible nut pieces fell from any of the other DCS/stud holes.

Orbiter umbilical camera films showed nominal separation of SRB's from the External Tank and normal separation of the ET from the Orbiter. The LO2 ET/ORB umbilical TPS was undamaged. All lightning contact strips were intact. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. The LH2 ET/ORB umbilical appeared to be in good condition with little or no TPS damage. Foam was missing or eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut. A thin, metallic object with straight edges (lightning contact strip) originated from the LH2 ET/ORB umbilical area shortly after umbilical separation and drifted in a general -Y-Z direction. Two of the five lightning contact strips from the LH2 umbilical appeared to be missing. Loss of lightning contact strips was the subject of a previous IFA.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The number of MSA-2 debonds on both frustums was less than average.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-102 was conducted 9 March 1996 on SLF runway 33 at the Kennedy Space Center. The Orbiter TPS sustained a total of 96 hits, of which 17 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of hits and the number of hits 1-inch or larger was less than average.

The Orbiter lower surface sustained a total of 55 hits, of which 11 had a major dimension of 1-inch or larger. The largest lower surface tile damage site occurred on the right inboard elevon and measured 5.0-inches long by 1.0-inch wide by 0.75-inch maximum depth. Hits on the right side along a line from nose to tail are generally attributed to ice impacts from the ET LO2 feedline bellows and support brackets.

ET/Orbiter separation devices EO-1 and EO-3 functioned normally. The EO-2 debris container iris was obstructed and had not closed fully. No ordnance fragments were found on the runway beneath the umbilical cavities. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the facility environment, SRB BSM exhaust, Orbiter RCS nozzle cover adhesive, Orbiter TPS, and paints/primers from various sources. These residual sampling data do not indicate a single source of damaging debris as all of the noted materials have previously been documented in post-landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

A total of seven Post Launch Anomalies, but no In-Flight Anomalies (IFA's), were observed during the STS-75 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 21 February 1996 at 1500 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC Chief, ET/SRB Mechanical Systems
G. Katnik	NASA - KSC Shuttle Ice/Debris Systems
J. Lin	NASA - KSC Shuttle Ice/Debris Systems
B. Davis	NASA - KSC Digital Imaging Systems
R. Speece	NASA - KSC Thermal Protection Systems
B. Bowen	NASA - KSC Infrared Scanning Systems
J. Rivera	NASA - KSC ET Mechanisms/Structures
M. Bassignani	NASA - KSC ET Mechanisms/Structures
M. Valdivia	LMSO - SPC Supervisor, ET/SRB Mechanical Systems
R. Seale	LMSO - SPC ET Mechanical Systems
J. Blue	LMSO - SPC ET Mechanical Systems
W. Richards	LMSO - SPC ET Mechanical Systems
M. Wollam	LMSO - SPC ET Mechanical Systems
G. Fales	LMSO - SPC ET Mechanical Systems
Z. Byrns	NASA - KSC Level II Integration
K. Mayer	Rockwell LSS Systems Integration
W. Atkinson	Rockwell LSS Systems Integration
R. Harmon	THIO - LSS SRM Processing
S. Otto	LMSO - LSS ET Processing
J. Stone	RI-DNY Shuttle Aerodynamics

3.0 LAUNCH

STS-75 was launched at 96:53:20:18:00.004 GMT (3:18 p.m. local) on 22 February 1996.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 21 February 1996. The detailed walkdown of Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (19th flight), ET-76 (LWT 69), and BI-078 SRB's. There were no significant vehicle or launch pad anomalies.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 22 February 1996 from 1000 to 1155 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. No acreage icing or frost conditions were expected due to the mid-afternoon launch time. There were no protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, particularly those areas not visible from remote fixed scanners, and to scan for unusual temperature gradients.

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. The F4R RCS thruster cover was tinted green indicating a small internal vapor leak. Ice/frost had formed along the full 360 degree circumference of the SSME #1 and #2 heat shield-to-nozzle interfaces. Frost extended across the engine mounted heated shield to the DMHS closeout blanket at the 6:00 o'clock position. Only condensate was present on the SSME #3 heat shield. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers averaged 81-84 degrees F. Temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 66-83 degrees F depending on sun position and shadows. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature supplied by THIO was 61 degrees F, which was within the required range of 44-86 degrees F.

3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Final Inspection Team observed light condensate, but no ice or frost accumulations, on the LO2 tank. There were no TPS anomalies.

The intertank acreage exhibited no TPS anomalies. Residue and some possible surface etching on the GUCP surfaces from the previous day sodium hydroxide spill was visible.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost accumulation, was present on the acreage. A crack, 10-inches long by 3/8-inch wide, was present in the -Y vertical strut attachment fitting fairing forward surface TPS. The presence of the crack was acceptable for flight per NSTS-08303 criteria. There were no anomalies on the new-method bipod jack pad closeouts.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice/Frost Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, consisted of four OTV recorded items.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch. Dust, or particulate matter, possibly the result of the sodium hydroxide spill from the previous day, accumulated in the bottom of most sound suppression water troughs. The presence of the particulates was not a debris concern for launch.

No leaks were observed on the GUCP or either of the LO2 and LH2 Orbiter T-0 umbilicals, though heavier than usual frost had formed on the purge shrouds.

A 4-inch long metal snap ring was recovered from the LH2 TSM west side pipe support.

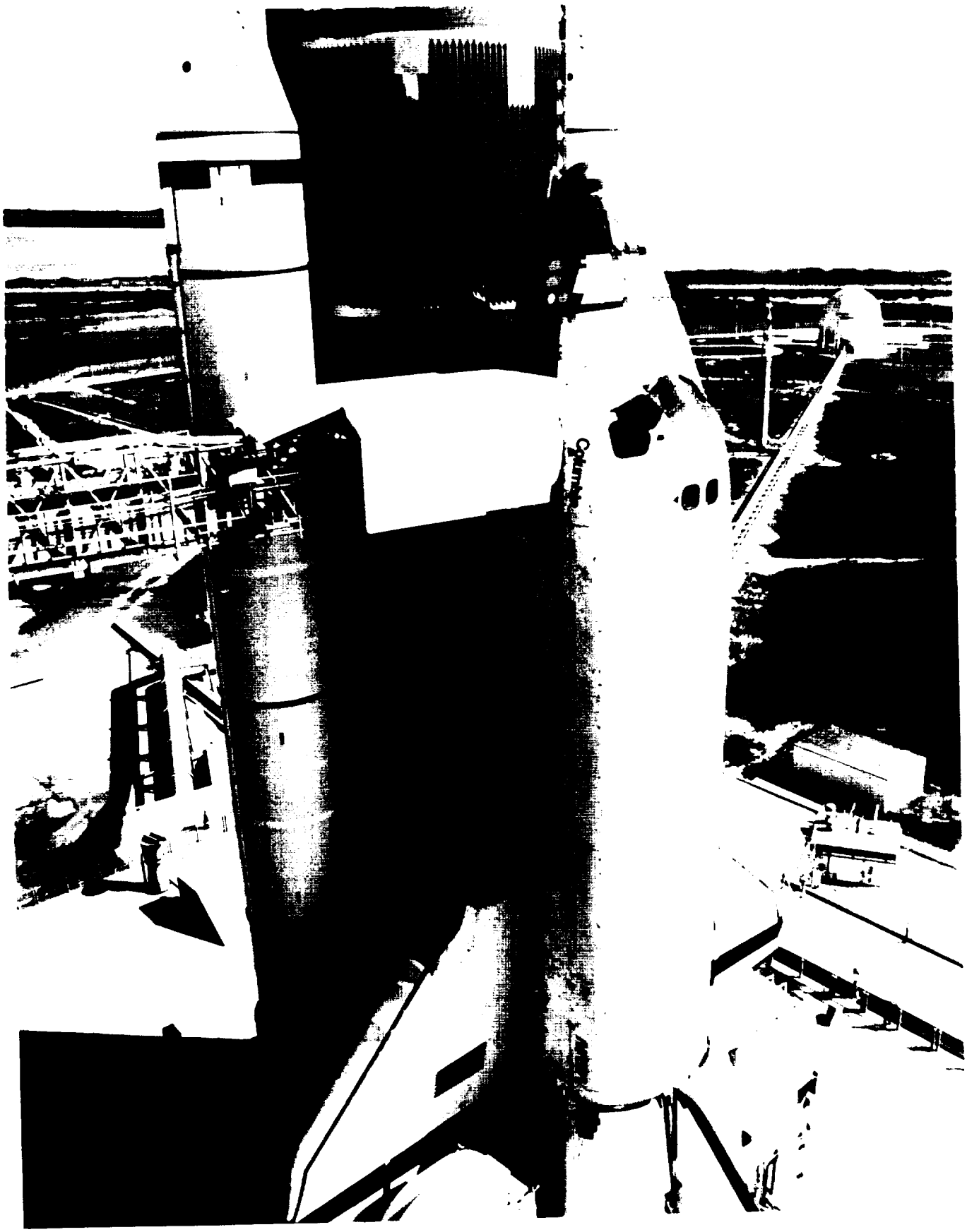


Photo 2: STS-75 Cryoloaded for Launch

OV-102 Columbia (19th flight), ET-76 (LWT 69), and BI-078 SRB's

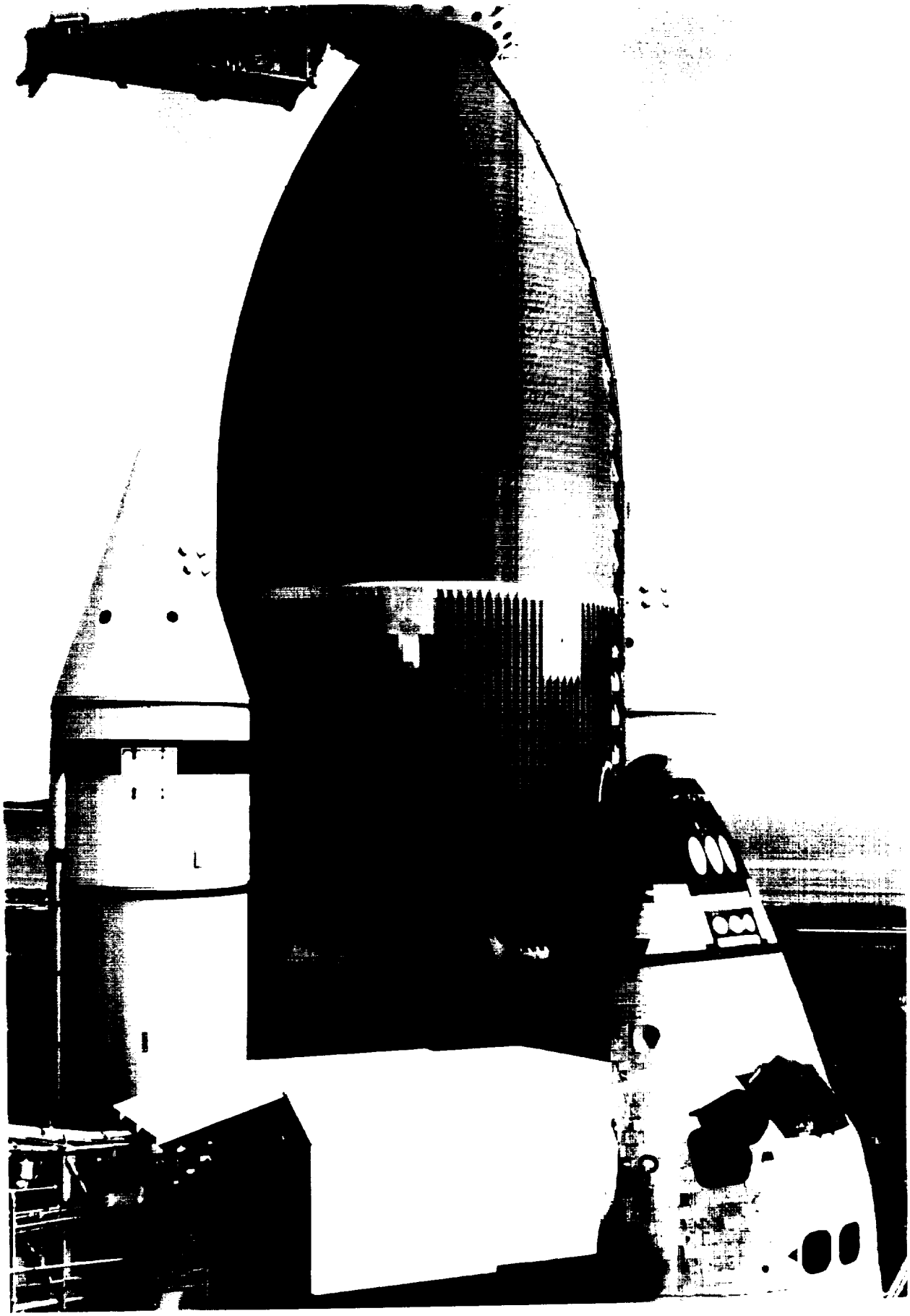


Photo 3: ET-76 Cryoloaded for Launch

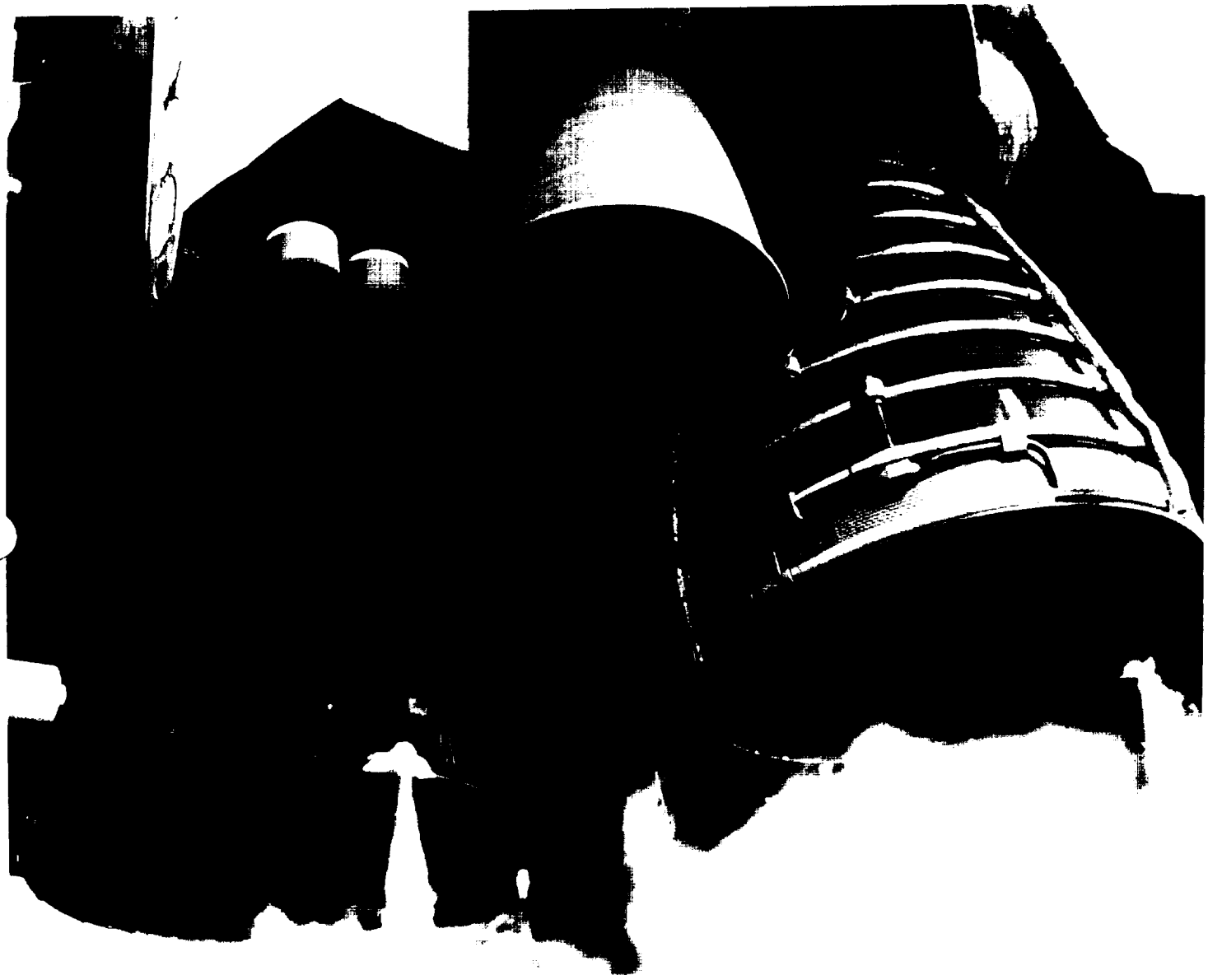


Photo 4: Overall View of SSME's

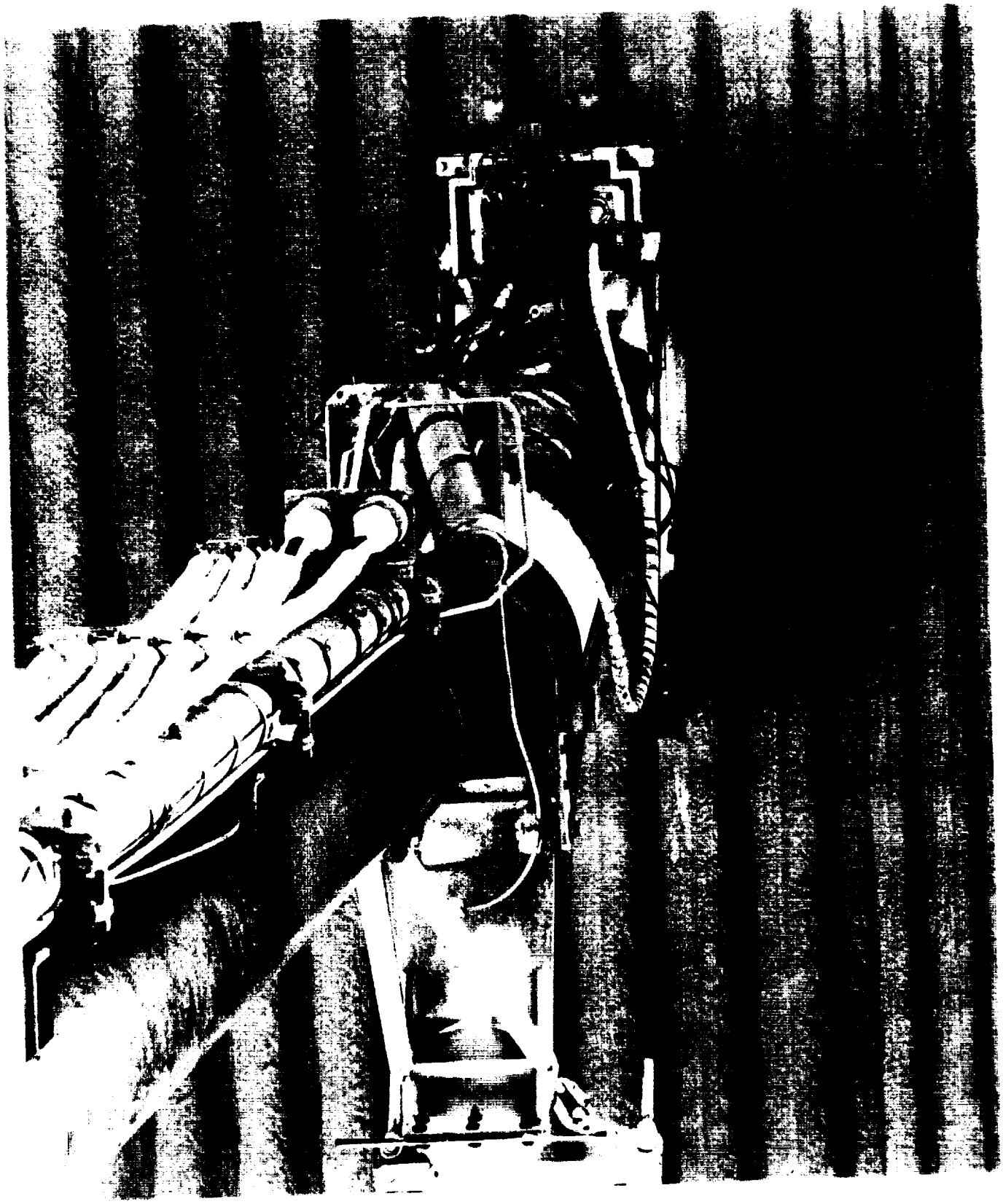


Photo 5: Sodium Hydroxide Residue on GUCP

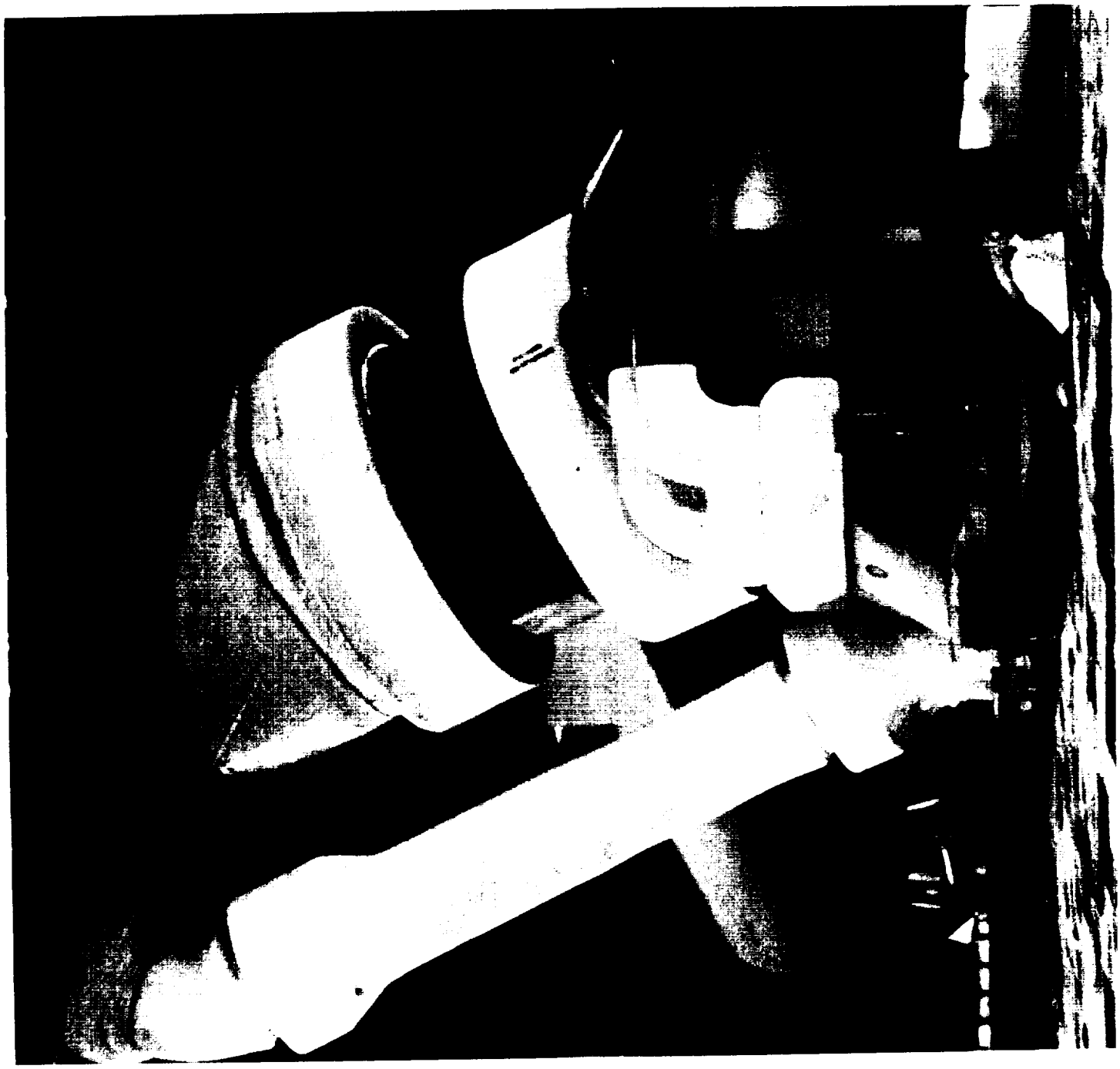


Photo 6: ET/ORB LH2 Umbilical

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, RSS, and Pad B crawlerway/acreage was conducted for two hours on 22 February 1995 starting at 1630 hours.

No flight hardware or TPS materials were found.

South SRB hold down post (HDP) erosion was typical. All south HDP shoe EPON shim material was intact except for a small tear and a debond in the HDP #2 shim. Rockwell-Downey reported a 0.20g lateral acceleration at liftoff. HDP #5 stud hole exhibited burrs around the +Z edge, a visual indication of a stud hang-up. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was typical. Minor damage to the SRB aft skirt purge lines and T-0 umbilicals was similar to previous launches.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent hood appeared undamaged. No topcoat from the External Tank nosecone had adhered to the GOX vent hood seals.

The GH2 vent line had no loose cables, and appeared to have latched properly with no rebound. The GUCP legs and crossbeam showed no obvious signs of contact by the static retract lanyard. The vent line was latched on the eighth tooth of the latching mechanism. The RSS cable had disconnected properly. One latch back retainer spring was broken. The GUCP frame and legs were etched/discolored from the caustic sodium hydroxide leak of 21 February 1996.

The earth berm in the path of the SRB exhaust was moderately eroded. Most of the stakes behind the berm were still upright. The berm successfully protected a portion of the pad perimeter fence from debris impacts.

Overall, damage to the pad appeared minimal.

Post launch pad inspection anomalies are listed in Section 9.

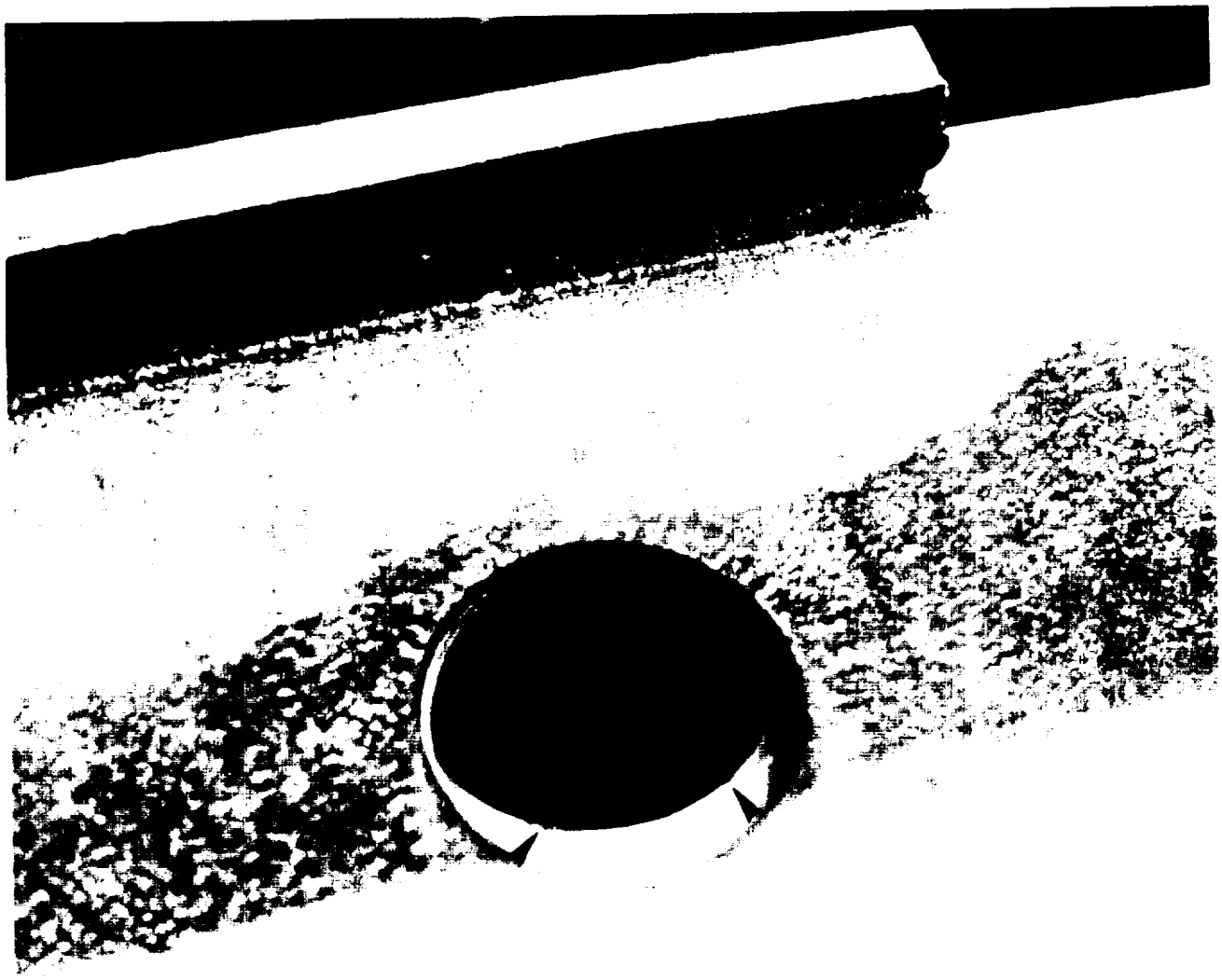


Photo 7: HDP #5 Stud Hang-Up

HDP #5 stud hole exhibited burrs around the +Z edge, a visual indication of a stud hang-up

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review. Post flight anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 102 films and videos, which included thirty-nine 16mm films, twenty 35mm films, four 70mm films, and thirty-nine videos, were reviewed starting on launch day.

SSME ignition appeared normal. Free burning hydrogen appeared to be less than usual during SSME startup. A dark spot on the inside wall of the SSME #2 nozzle may be a weld or repair (E-76). A flash, or flare, was visible in the SSME #2 Mach diamond shortly after T-0 (E-31).

SSME ignition caused ice to fall from the ET/ORB umbilicals. Several pieces of ice contacted the LH2 umbilical cavity sill and were deflected outward. No tile damage was visible (OTV 109).

A thin, flexible, 6-inch by 1-inch object, believed to be a GSE tile shim, first entered the field of view near the LH inboard elevon +Z side at 20:17:58.379 GMT. The object appeared to contact the aft fuselage sidewall near the body flap hinge area and the lower portion of the SSME #2 nozzle while falling aft. No resulting damage was visible (E-18).

Small pieces of tile surface coating material were lost from 5 places on the base heat shield near SSME #3 (E-17, -19), 4 places on the base heat shield outboard of SSME #2 (E-18), and 3 places on the aft LH RCS stinger heat shield (E-20).

Two small pieces of facility debris entered the field of view prior to T-0. No contact with flight hardware was observed (E-30).

GUCP disconnect from the ET was nominal (E-33). GH2 vent line retraction and latch were normal. Slack in the static retract lanyard was minimal (E-41, -50, -60; OTV 104, 167).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150).

A stud hang-up occurred on holddown post #5. As the vehicle gained altitude and the LH aft skirt cleared the stud, a semi-circular piece of aluminum from the stud hole wall fell onto the southwest corner of the HDP shoe and then downward into the haunch area. Two fragments that may have been aluminum shavings fell from the stud hole area (E-12, -13).

No stud hang-ups occurred on any of the other holddown posts. No ordnance fragments or frangible nut pieces fell from any of the other DCS/stud holes. HDP #2 EPON shim adhesive or grease was visible burning after the vehicle cleared the tower (E-8).

A small piece of RH aft skirt foam broke loose when the nitrogen purge line disconnected (E-8).

Numerous pieces of SRB throat plug material and shredded SRB sound suppression water trough material were ejected out of the SRB exhaust holes and passed by the SRB aft skirts moving away from the vehicle shortly after T-0.

A piece of RH aft skirt thermal curtain tape was loose at liftoff (E-7).

Movement of the GOX vent hood in the SRB plume after the vehicle cleared the tower appeared to be similar to previous launches and resulted in no unusual damage (E-62).

Ice falling aft from the ET/ORB umbilicals after the vehicle cleared the tower made "glancing" contact with lower surface tiles, but no damage was observed (E-52).

A bird passing behind the ET/RH SRB from the E-52 eastern tracker vantage point at 20:18:08.356 GMT was not near the vehicle (did not appear in western tracker fields-of-view).

Several bright flashes occurred in the SSME plume during ascent. This phenomenon has been observed on previous launches and is believed to be caused by debris passing through the exhaust plume (E-222, -223; TV-4B, TV-21B).

Localized flow condensation formed on various parts of the vehicle at altitude as expected for the ambient weather conditions (E-220, -224; TV-5B, TV-21B).

Body flap movement (amplitude and frequency) appeared similar to previous flights (E-213,-220).

ET aft dome charring, exhaust plume recirculation, and SRB separation appeared nominal (E-207, -212).

A considerable portion of the long range tracking coverage was obscured by haze.

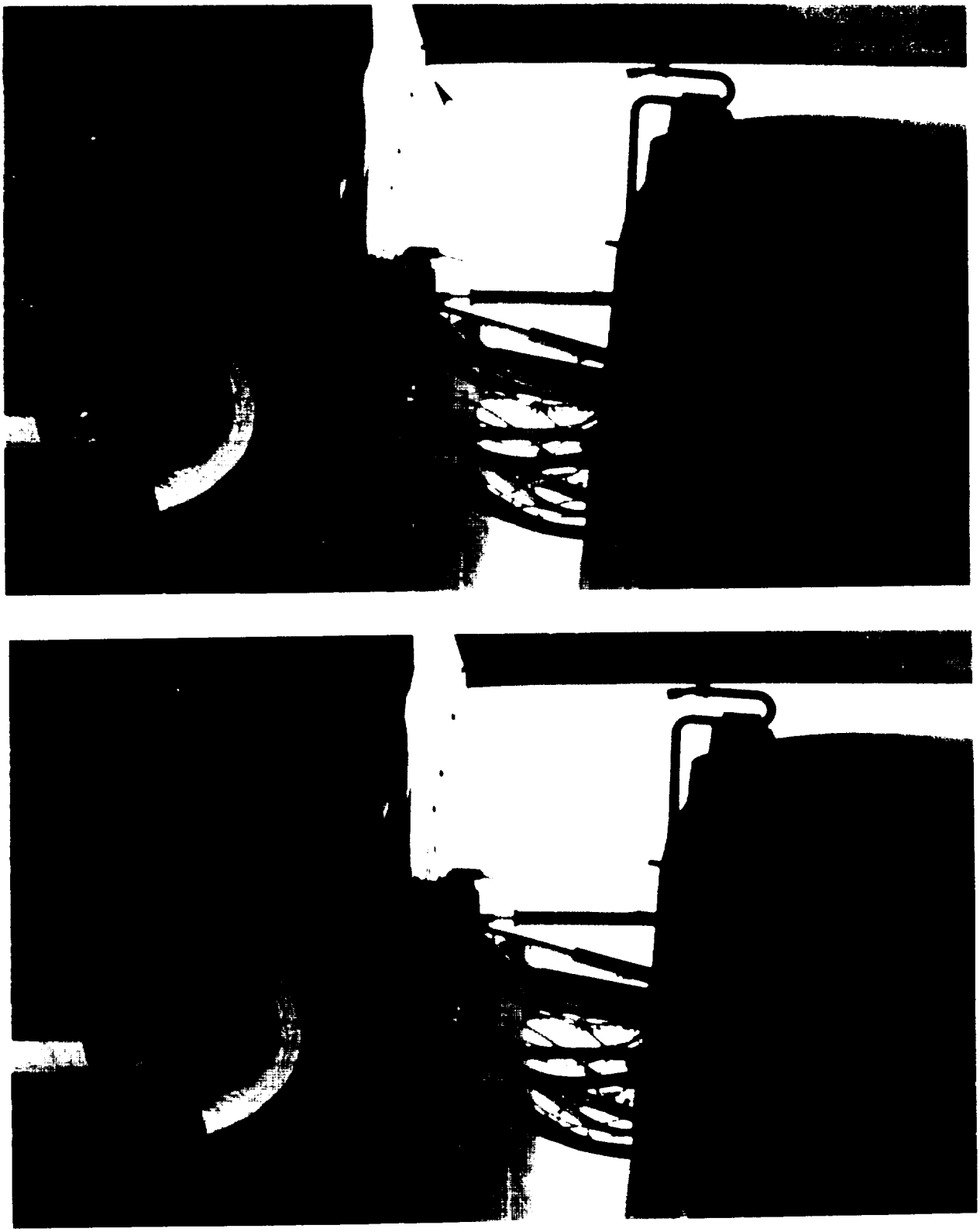


Photo 8: GSE Tile Shim

A thin, flexible, 6-inch by 1-inch object, believed to be a GSE tile shim, first entered the field of view near the LH inboard elevon +Z side at 20:17:58.379 GMT. The object appeared to contact the aft fuselage sidewall near the body flap hinge area and the lower portion of the SSME #2 nozzle while falling aft. No resulting damage was visible

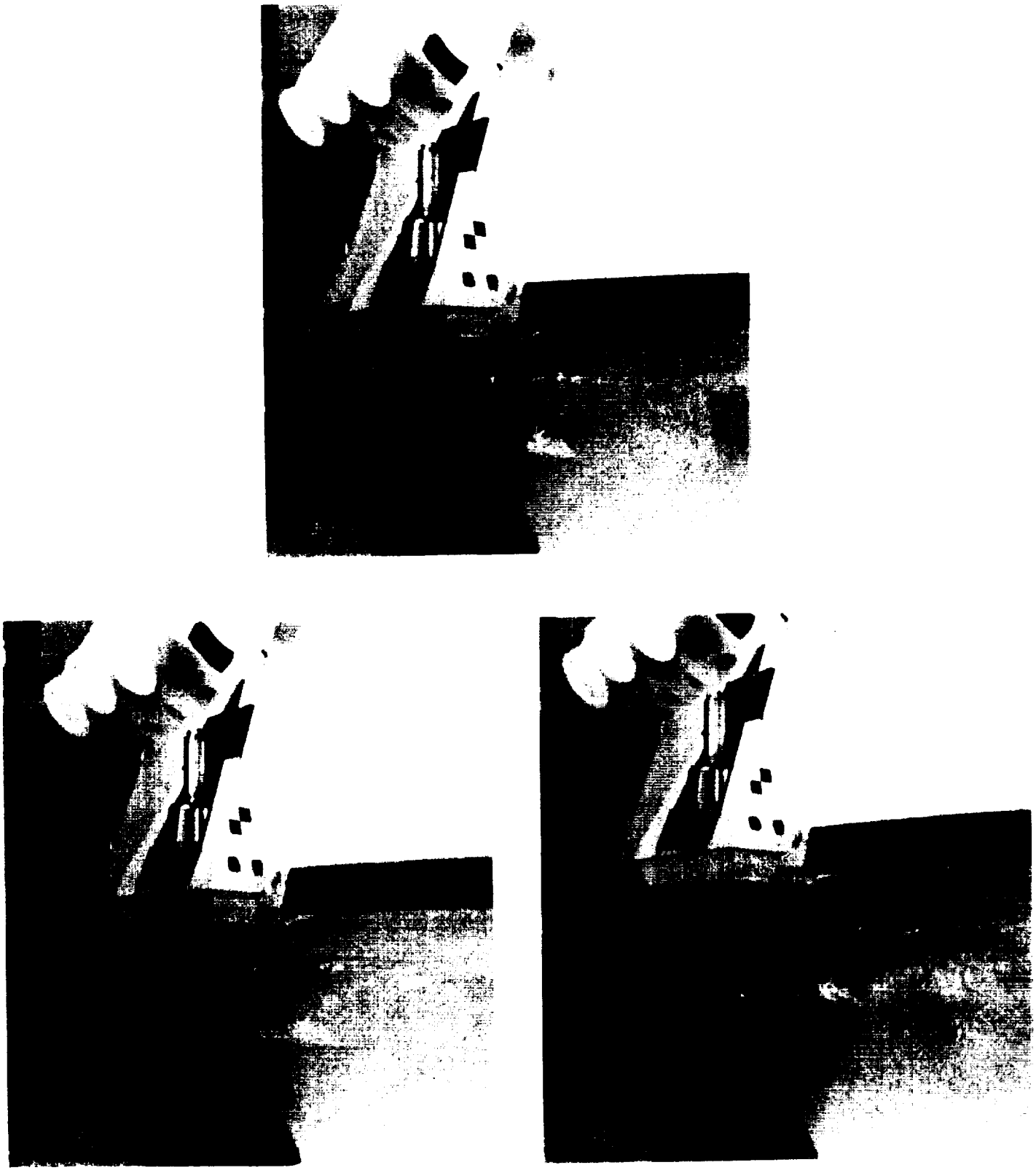


Photo 9: HDP #5 Stud Hang-Up

A stud hang-up occurred on holddown post #5. As the vehicle gained altitude and the LH aft skirt cleared the stud, a semi-circular piece of aluminum from the stud hole wall fell downward into the haunch area. Two fragments that may have been aluminum shavings fell from the stud hole area.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-102 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. Data was obtained from all three cameras. Hand held photography taken by the flight crew consisted of seven 35mm images.

No vehicle damage or lost flight hardware was observed that would have been a safety of flight concern.

SRB separation from the External Tank was nominal.

ET-76 separation from the Orbiter also appeared normal. The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, PAL ramps, and LO2 feedline. Likewise, no -Z side acreage TPS anomalies were detected on the LO2 tank, intertank, and LH2 barrel.

The umbilical films revealed no ET intertank acreage divots. However, four divots, ranging in size from 6 to 12-inches in diameter, were visible in the intertank-to-LH2 tank flange closeout (one in the -Y+Z quadrant; three in the +Y+Z quadrant near the EB fitting). In addition, a 5-inch diameter divot was observed in the LH2 tank acreage near the group of three divots in the flange closeout.

Both bipod jack pad closeouts were intact.

Erosion of TPS from the LO2 feedline flange closeouts and support brackets, thrust strut flange closeouts, and LH2 tank pressurization line ramps was typical.

The LH2 ET/ORB umbilical appeared to be in good condition with little or no TPS damage. Foam was missing or eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut. A thin, metallic object with straight edges (lightning contact strip) originated from the LH2 ET/ORB umbilical area shortly after umbilical separation and drifted in a general -Y-Z direction. Two of the five lightning contact strips from the LH2 umbilical appeared to be missing.

The LO2 ET/ORB umbilical TPS was undamaged. All lightning contact strips were intact. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray.

Photo 10: Loose Lightning Contact Strip

A thin, metallic object with straight edges (lightning contact strip) originated from the LH2 ET/ORB umbilical area shortly after umbilical separation and drifted in a general -Y-Z direction.

Photo 11: LH2 ET/ORB Umbilical After Separation

The LH2 ET/ORB umbilical appeared to be in good condition with little or no TPS damage. Foam was missing or eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut. Two of the five lightning contact strips from the LH2 umbilical appeared to be missing (arrows).

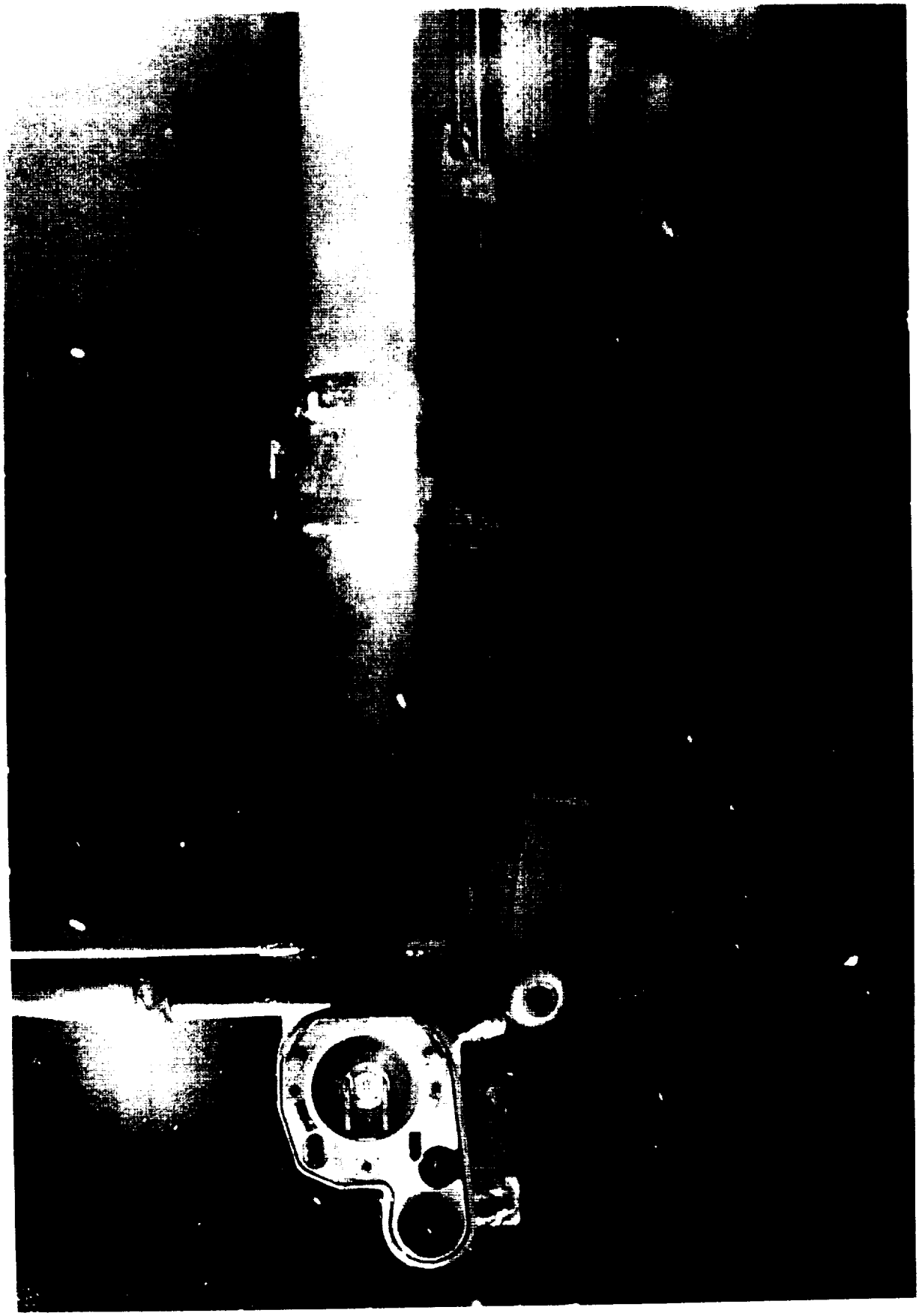


Photo 12: ET Separation from Orbiter

The LO2 ET/ORB umbilical TPS was undamaged. All lightning contact strips were intact. Numerous divots/eroded areas were visible on the horizontal/vertical sections of the cable tray.

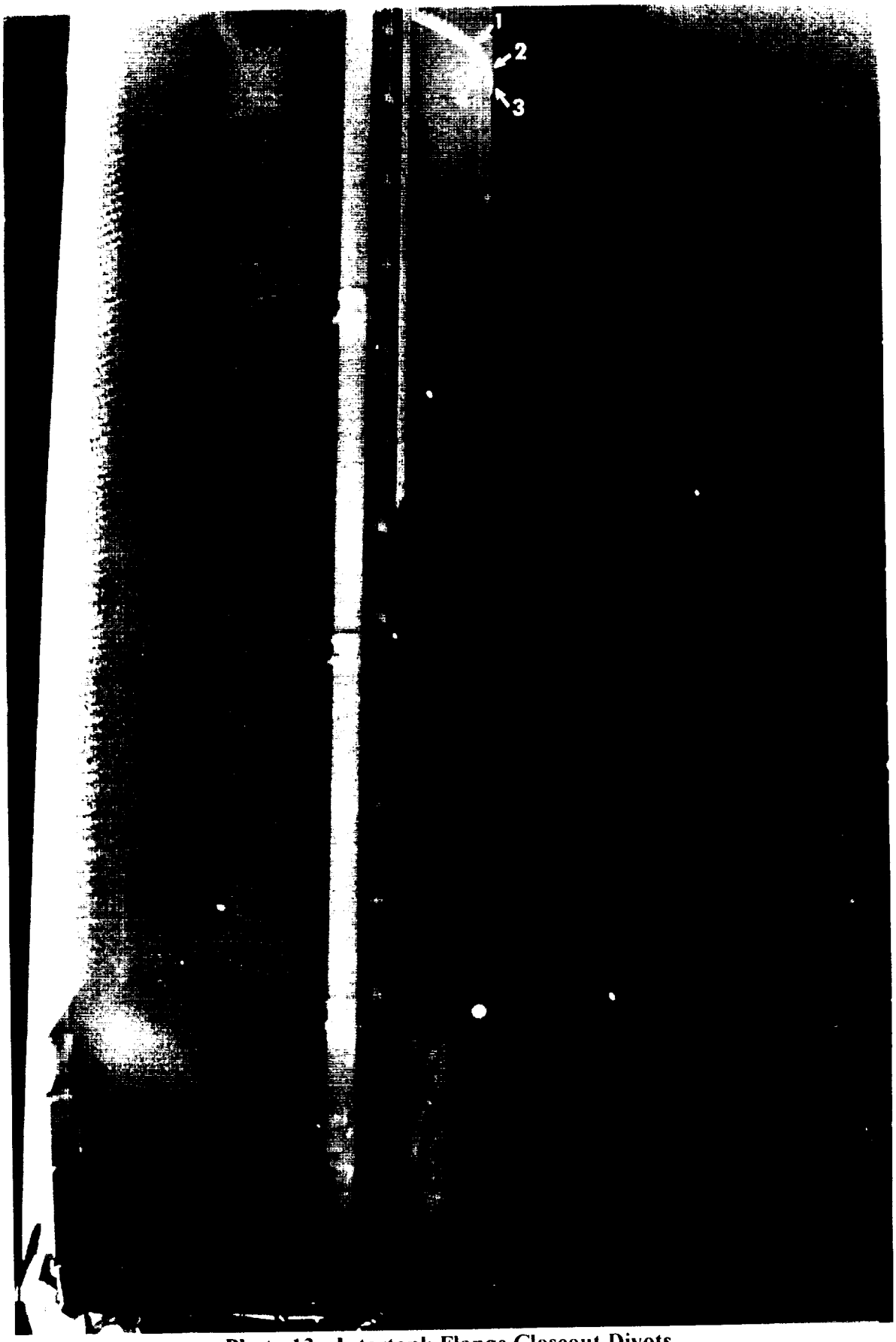


Photo 13: Intertank Flange Closeout Divots

Four divots, ranging in size from 6 to 12-inches in diameter, were visible in the intertank-to-LH2 tank flange closeout (arrows #1-4). In addition, a 5-inch diameter divot was observed in the LH2 tank acreage near the group of three divots in the flange closeout (arrow #5).

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 23 films and videos, which included nine 35mm large format films, two 16mm high speed films, and twelve videos, were reviewed.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. Left and right main landing gear touchdown was virtually simultaneous at approximately 2200 feet.

Drag chute deployment appeared nominal. However, the drag chute door bounced hard on the runway surface, became airborne, and impacted a runway edge light.

Touchdown of the nose landing gear was smooth.

No significant TPS damage was visible though the forward section of the left payload bay door exhibited a reddish-brown discoloration. Rollout and wheel stop were uneventful.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-078 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAS Hangar AF on 26 February 1996. From a debris standpoint, both SRB's were in excellent condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS. The number of debonds over fasteners (16) and over acreage (2) was less than average (Figure 1). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position.

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the frustum severance ring.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. No significant K5NA was missing from the separation plane of the upper strut fairing. The ETA ring, IEA, and IEA covers appeared undamaged. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt MSA-2 was intact. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

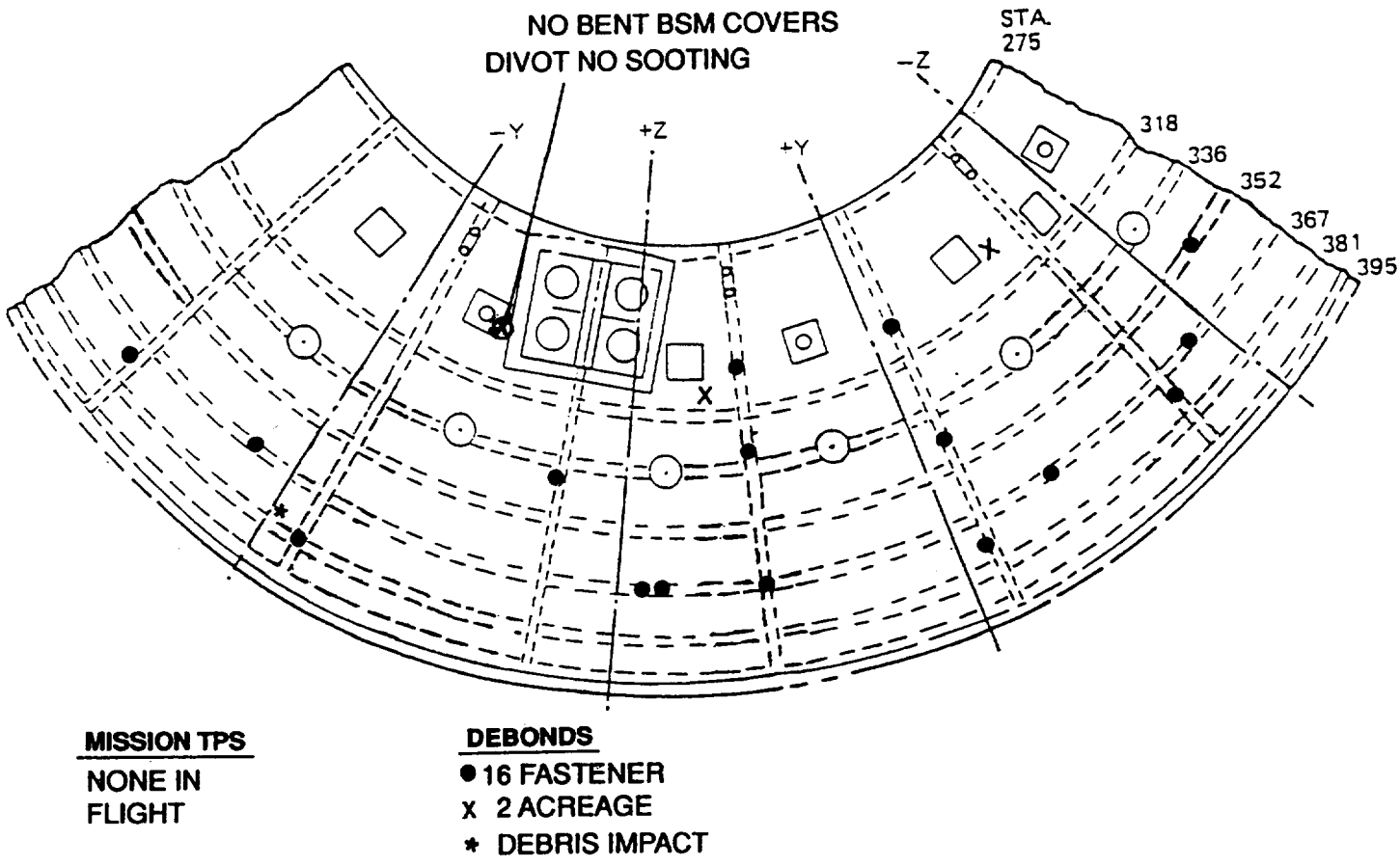


Figure 1: RH SRB Frustum

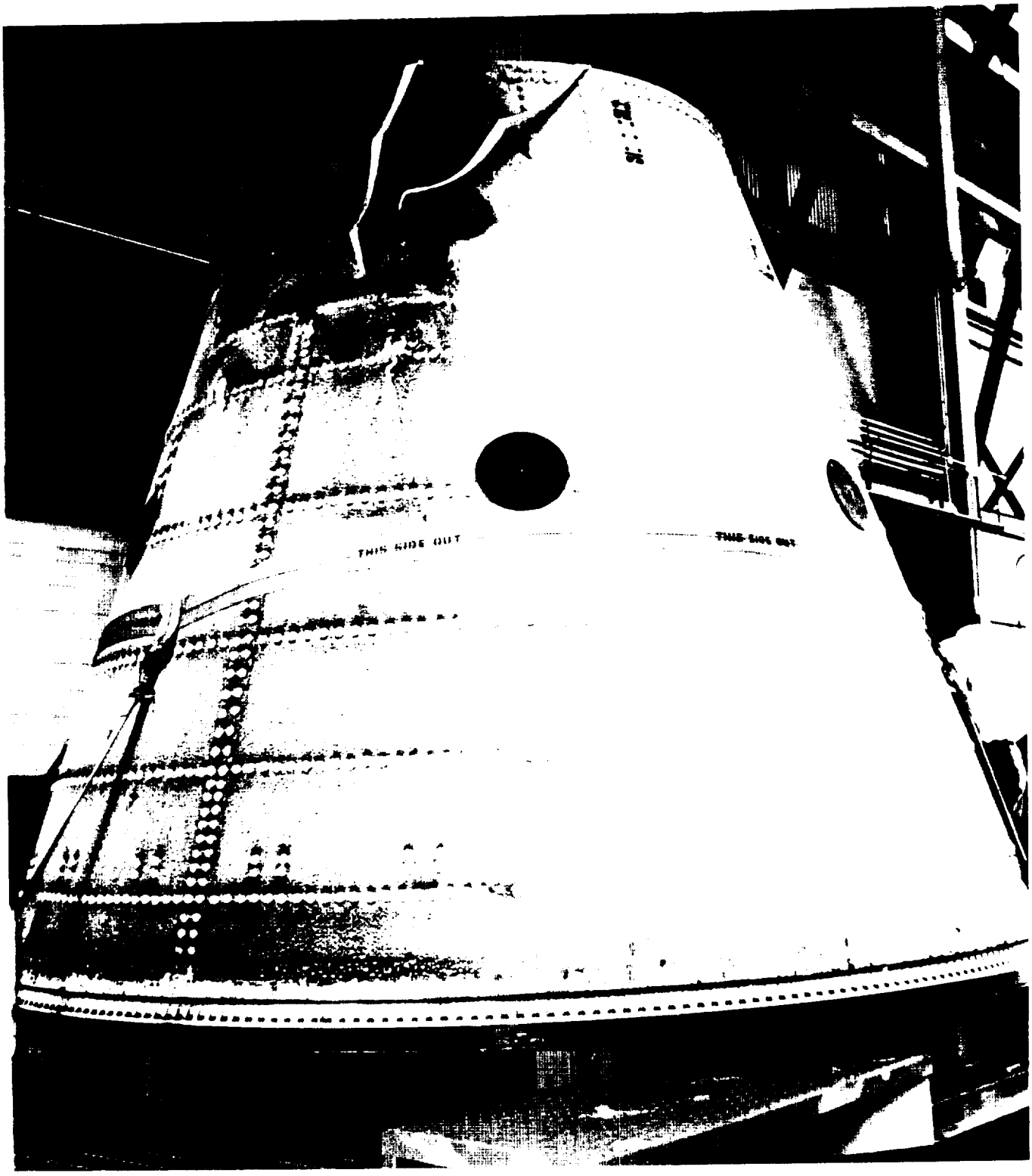


Photo 14: RH Frustum

The RH frustum was missing no TPS. The number of debonds over fasteners (16) and over acreage (2) was less than average. Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position.

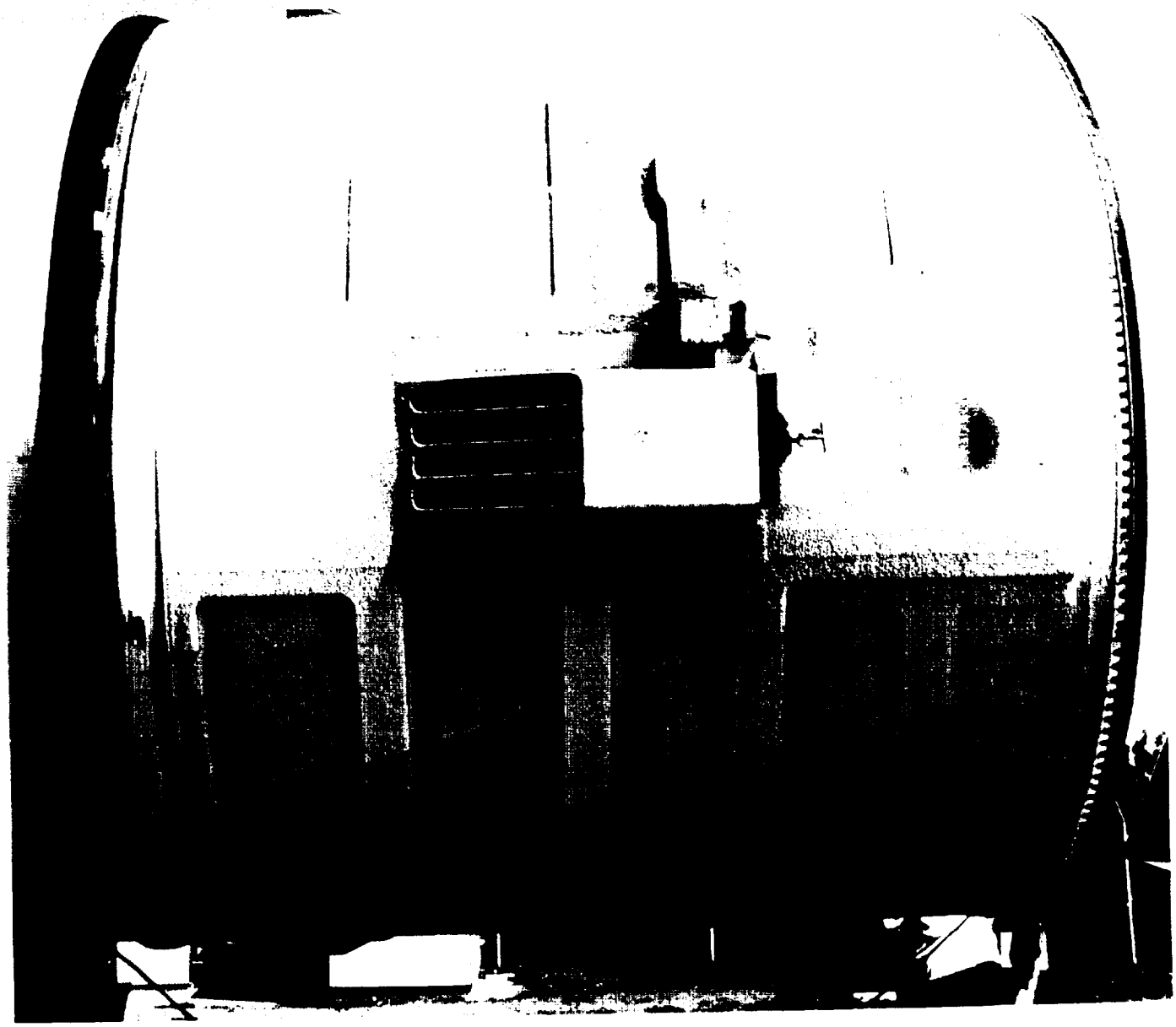


Photo 15: RH Forward Skirt

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the frustum severance ring.

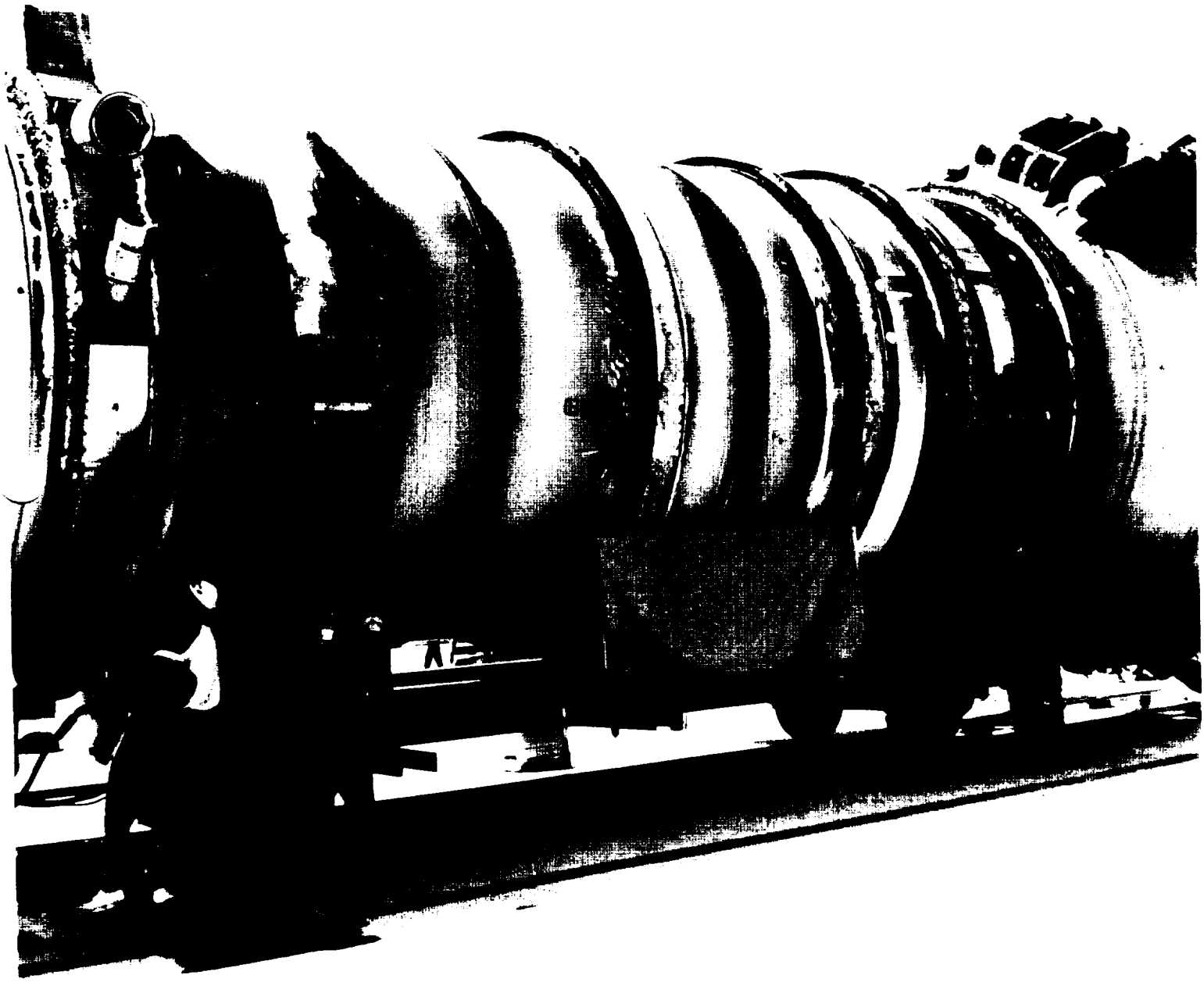


Photo 16: RH Aft Booster/ Aft Skirt

Separation of the aft ET/SRB struts appeared normal.

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS. The number of MSA-2 debonds over fasteners (20) was less than average (figure 2). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position though the two right cover attach rings had been bent by parachute riser entanglement after splashdown.

The LH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. None of the pins and retainer clips were missing from the frustum severance ring.

The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. No significant K5NA was missing from the separation plane of the upper strut fairing. The IEA and IEA covers appeared undamaged. The stiffener rings were damaged by water impact. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Numerous aft skirt MSA-2 divots exhibited clean substrates and adjacent material. Lack of sooting in the divots indicate occurrences late in flight or after splashdown.

A stud hang-up occurred on HDP #5 and the hole was broached. Stud thread impressions were visible in the stud hole wall. The stud hang-up was confirmed in the launch film review on film item E-12.

The HDP #6 and #7 Debris Containment System (DCS) plungers were obstructed by ordnance fragments and frangible nut halves, respectively. No anomalies on these two holddown posts were observed in the launch films and the two conditions were most likely caused by water impact.

SRB Post Launch Anomalies are listed in Section 9.

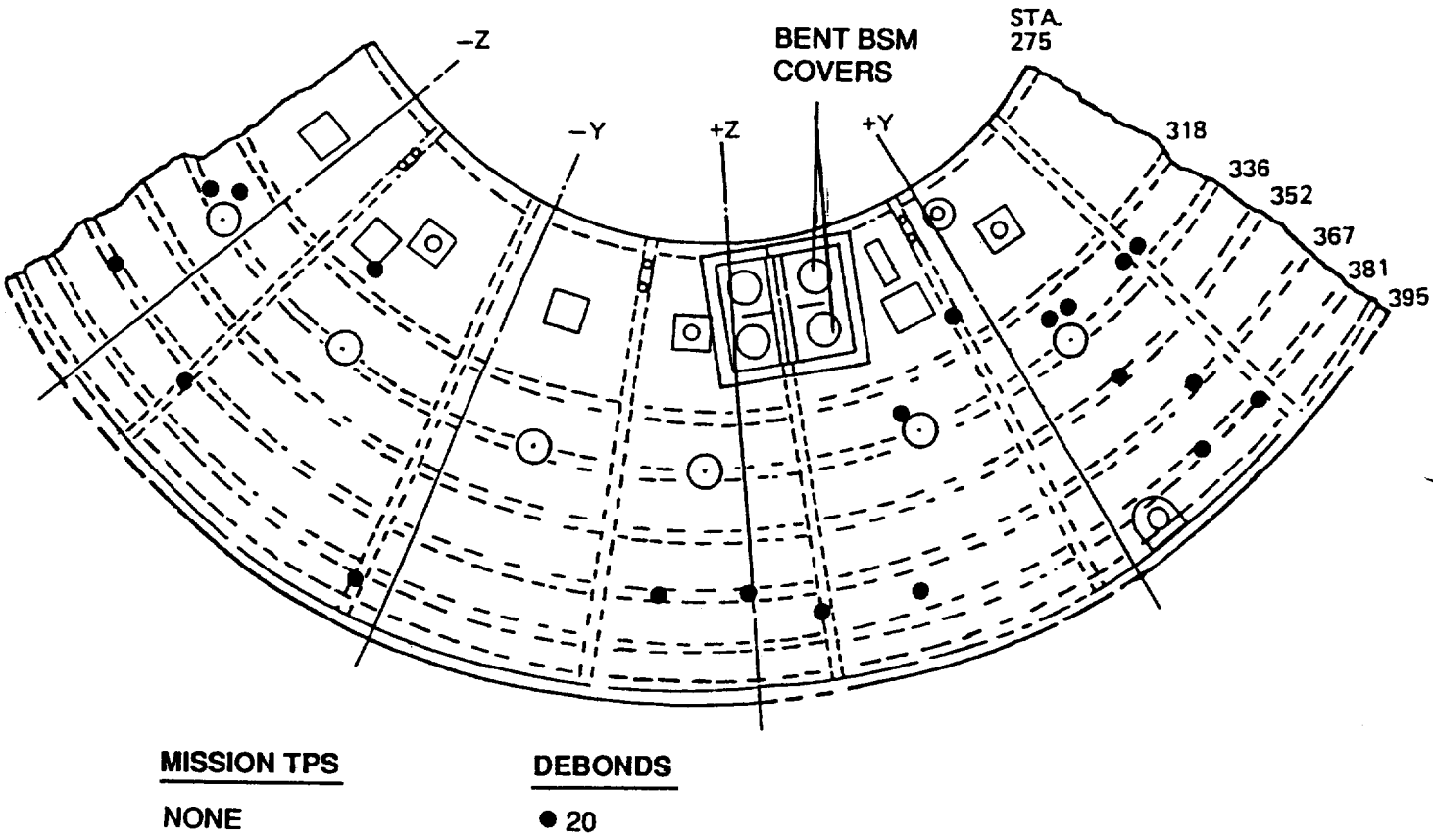


Figure 2: LH SRB Frustum

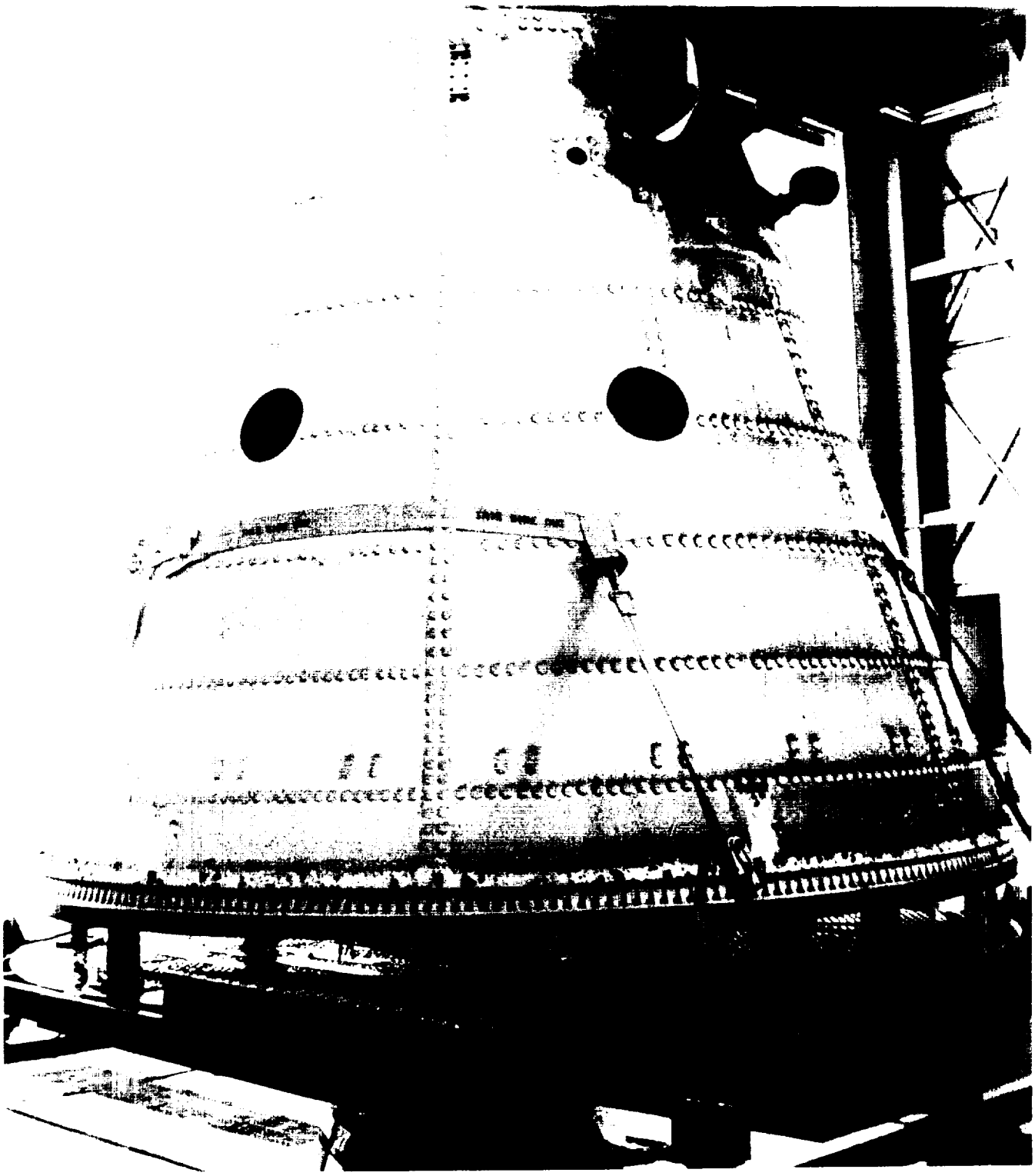


Photo 17: LH Frustum

The LH frustum was missing no TPS. The number of MSA-2 debonds over fasteners (20) was less than average. The BSM aero heat shield covers had locked in the fully opened position though the two right cover attach rings had been bent by parachute riser entanglement after splashdown.

Photo 18: LH Forward Skirt

The LH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. None of the pins/retainer clips were missing from the frustum severance ring.

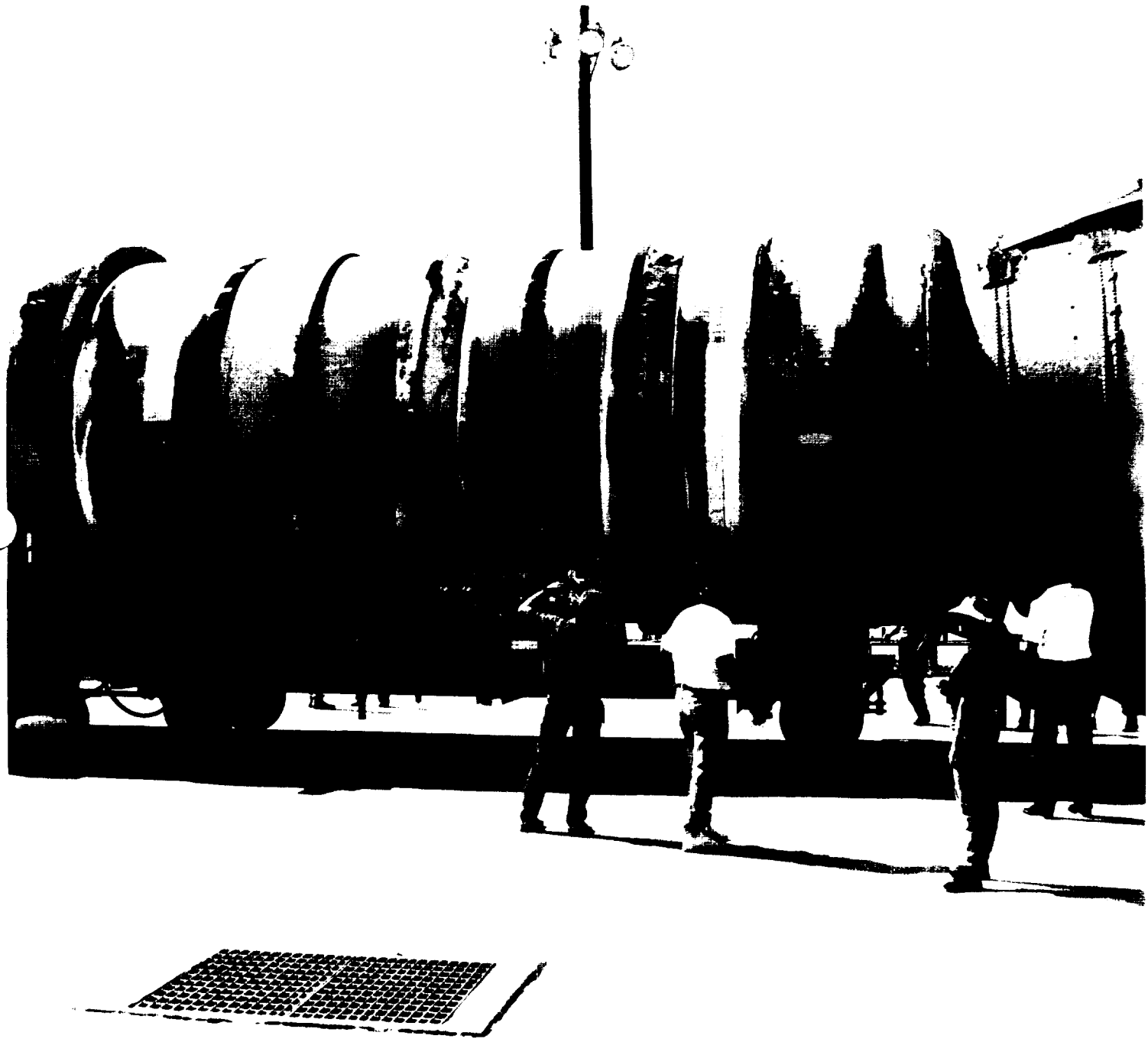


Photo 19: LH Aft Booster/ Aft Skirt

Photo 20: Stud Holes #5 and #6

A stud hang-up occurred on HDP #5 and the hole was broached. Stud thread impressions were visible in the stud hole wall (top view). The HDP #6 Debris Containment System plunger was obstructed by ordnance fragments. No anomalies on this holddown post were observed in the launch films and the condition was most likely caused by water impact (bottom view).

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-102 Columbia was conducted 9-11 March 1996 at the Kennedy Space Center on SLF runway 33 and in the Orbiter Processing Facility bay #2. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 96 hits, of which 17 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 58 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger was less than average (reference Figures 3-6).

The following table breaks down the STS-75 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	11	55
Upper surface	4	28
Right side	0	0
Left side	0	4
Right OMS Pod	1	3
Left OMS Pod	1	6
TOTALS	17	96

The largest lower surface tile damage site occurred on the right inboard elevon and measured 5.0-inches long by 1.0-inches wide by 0.75-inch maximum depth. Hits on the right side along a line from nose to tail are generally attributed to ice impacts from the ET LO2 feedline bellows and support brackets.

Tile damage sites aft of the LH2 and LO2 ET/ORB umbilicals, usually caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream, were typical in number and size.

No tile damage from micrometeorites or on-orbit debris have been identified to date.

The tires and brakes were reported to be in good condition for a landing on the KSC concrete runway.

ET/Orbiter separation devices EO-1 and EO-3 functioned normally. The EO-2 debris container iris was obstructed and had not closed fully. No ordnance fragments were found on the runway beneath the umbilical cavities. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly.

Right outboard flipper door #15 was dislocated from the rail.

The SSME #1 and #2 Dome Mounted Heat Shield (DMHS) closeout blankets were unstitched or torn at the 6-7:00 o'clock and 3-5:00 o'clock locations, respectively. The SSME #3 DMHS was in excellent condition with no damaged material. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged.

Tile damage sites on the upper surface of the body flap outboard of SSME #3 (6 places in the RTV coated area and 3 places along the edge) may have been caused by plume impingement from the downward firing R5D thruster. Visual inspection showed an approximate size of 5.5-inches by 3.5-inches by 0.25-inches deep at two of the tile damage locations.

No ice adhered to the payload bay door. However, a reddish-brown discoloration similar to that observed previously on OV-105 was present on the leading edge of the LH payload bay door. A discoloration around the F1L thruster was similar in appearance, but may not be related. Samples will be taken for microchemical analysis. No unusual tile damage was observed on the leading edges of the vertical stabilizer. The LH OMS pod leading edge tiles sustained one large hit measuring 5-inches long by 1.25-inches wide by 0.5-inches deep along with several smaller hits. This damage may have been caused by impacts from ice on the waste water dump nozzles.

Orbiter window hazing and streaking was typical. The numerous damage sites on the window perimeter tiles were attributed to a combination of new hits from FRCS thruster paper cover/adhesive and old tile repair material flaking off.

The post landing walkdown of Runway 33 was performed immediately after landing. All drag chute hardware was recovered and appeared to have functioned normally. The drag chute door had skidded along the runway and impacted a runway perimeter light. The major pieces of the light stanchion and lens were recovered.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger was less than average when compared to previous missions (Figure 7).

Post Landing Anomalies are listed in Section 9.0.

STS-75

DEBRIS DAMAGE LOCATIONS

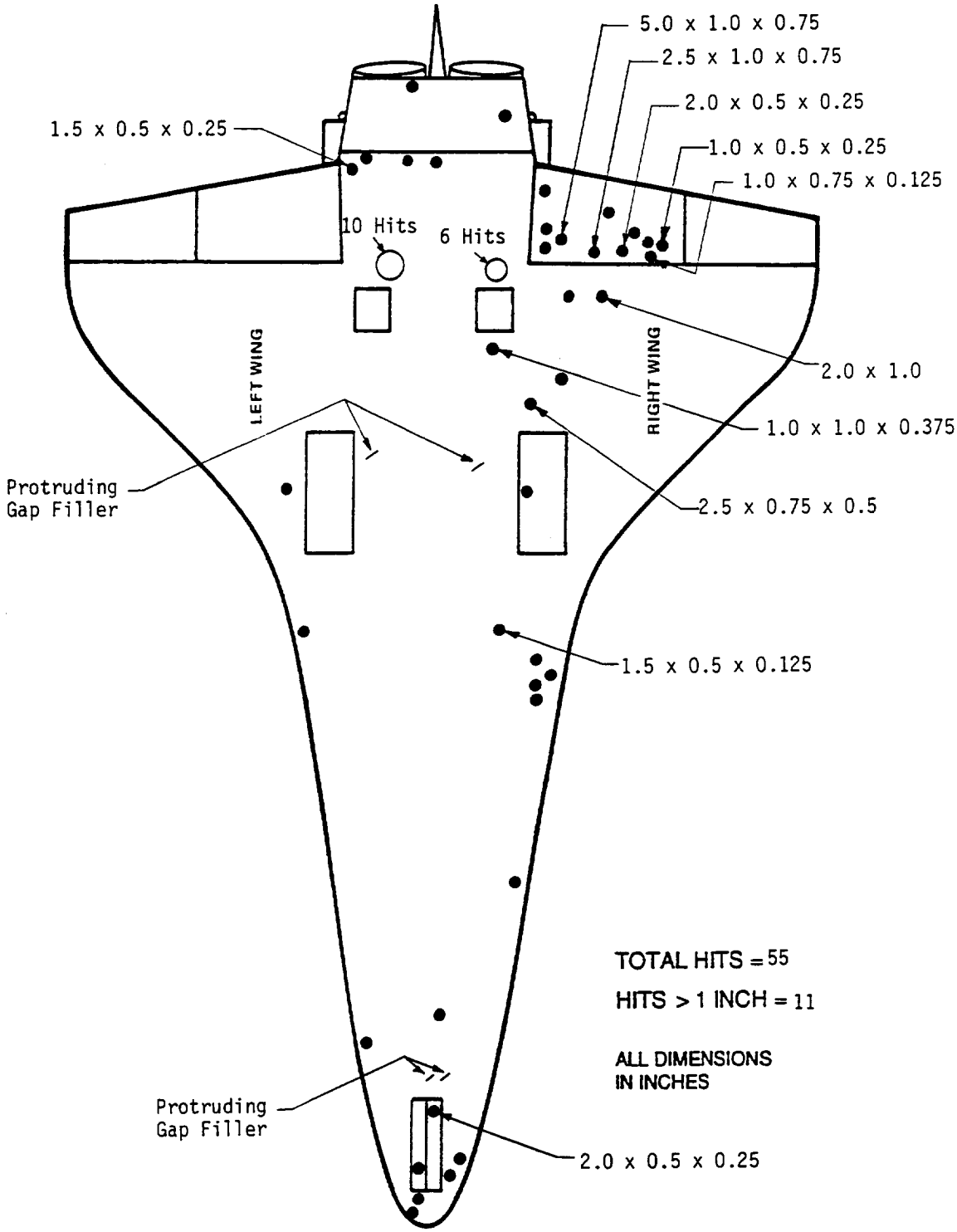


Figure 3: Orbiter Lower Surface Debris Map

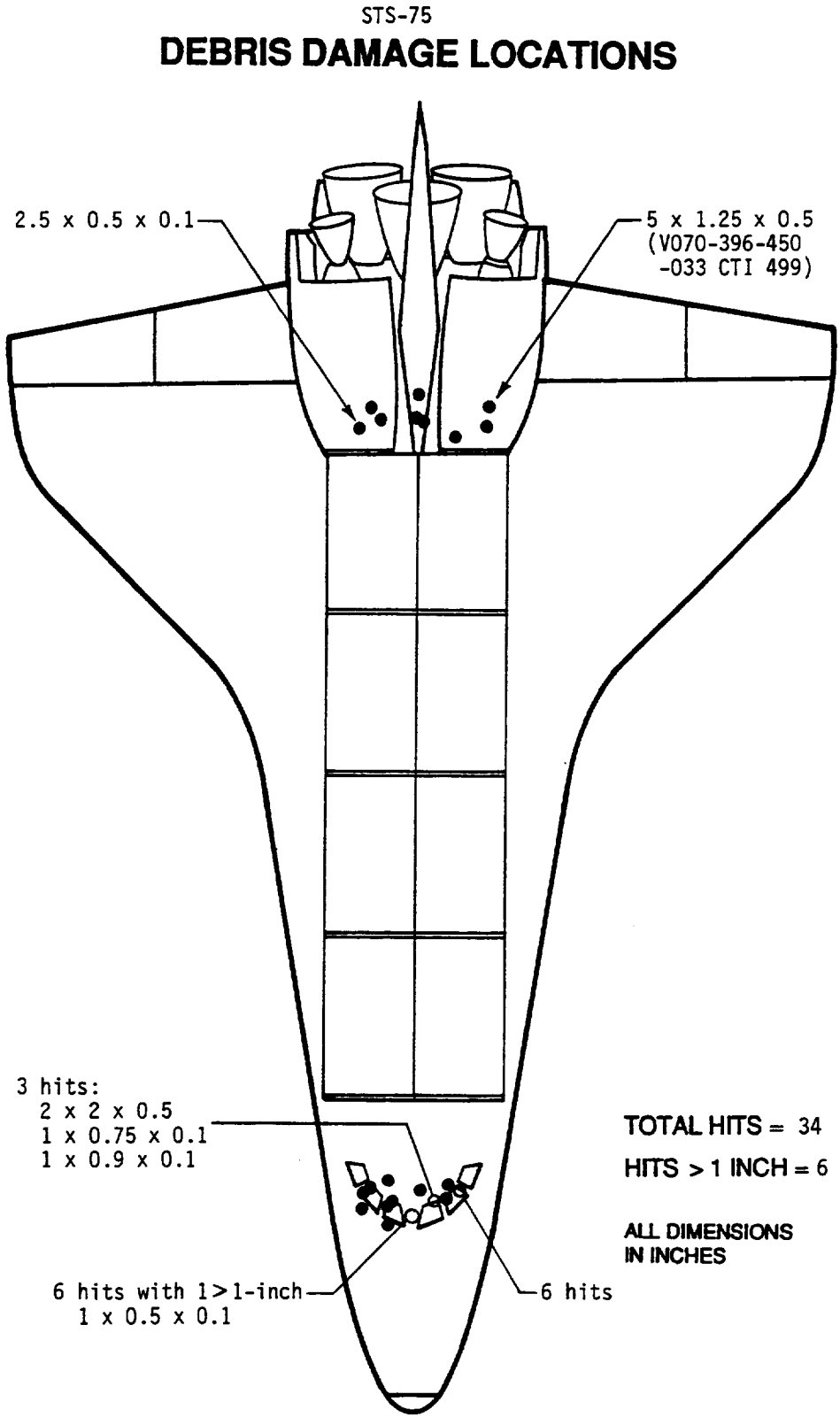
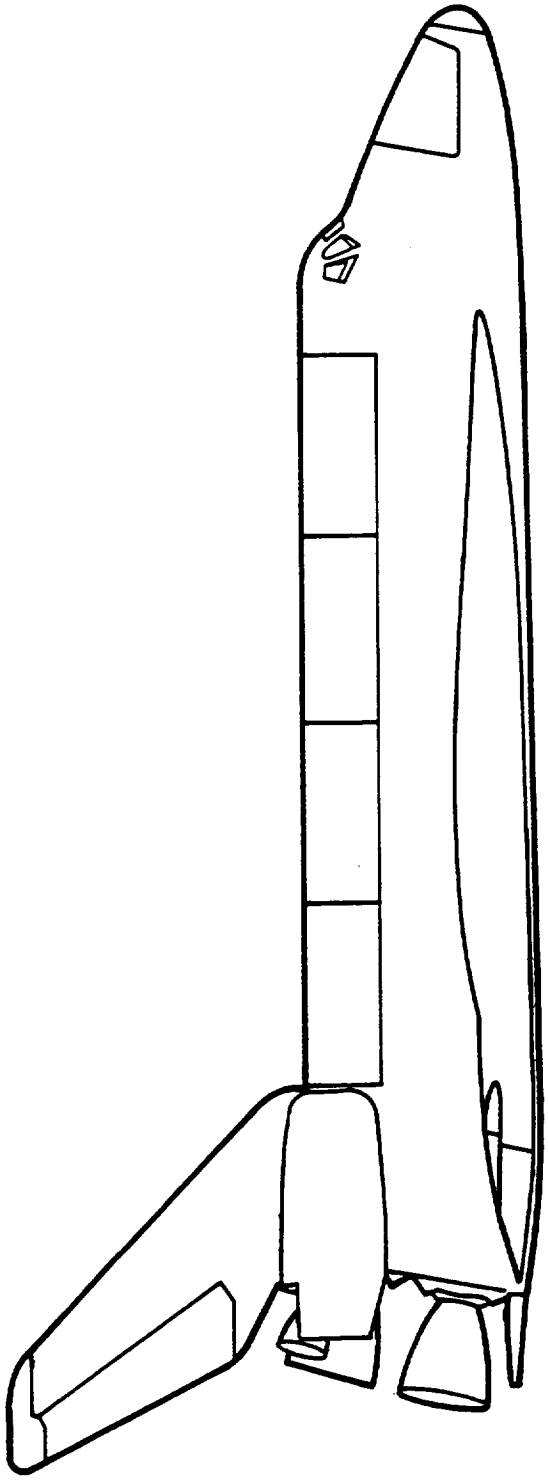


Figure 4: Orbiter Upper Surface Debris Map

STS-75

DEBRIS DAMAGE LOCATIONS



TOTAL HITS = 0

HITS > 1 INCH = 0

Figure 5: Orbiter Right Side Debris Map

STS-75

DEBRIS DAMAGE LOCATIONS

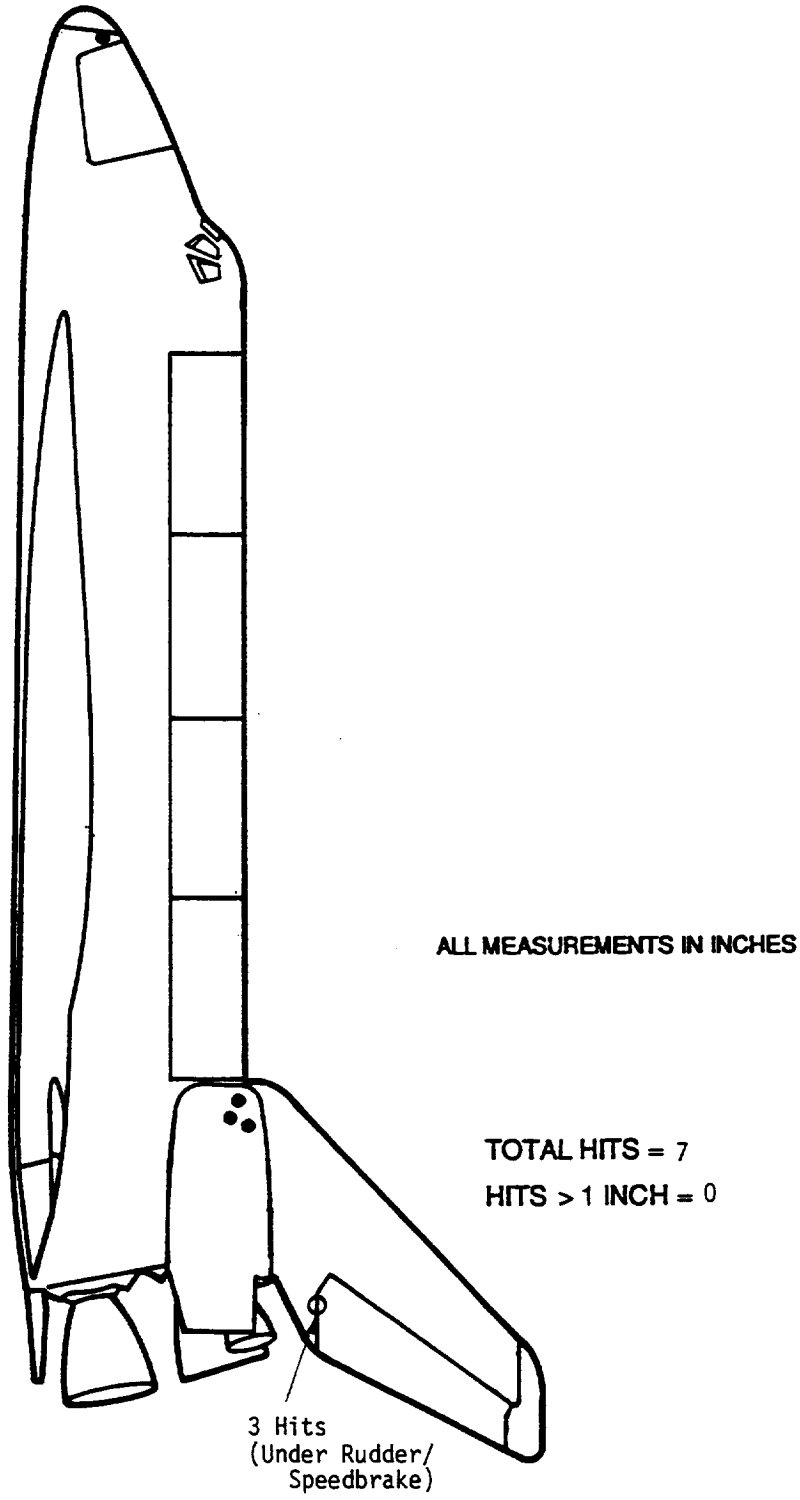


Figure 6: Orbiter Left Side Debris Map

ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	21	89	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
STS-63	7	84	14	125
STS-67	11	47	13	76
STS-71	24	149	25	164
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
STS-74	17	78	21	116
STS-72	3	23	6	55
AVERAGE	14.1	90.9	20.8	130.8
SIGMA	7.3	43.7	9.8	54.0
STS-75	11	55	17	96

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 7: Orbiter Post Flight Debris Damage Summary

Photo 21: Overall View of Orbiter Left Side

Photo 22: Overall View of Orbiter Right Side

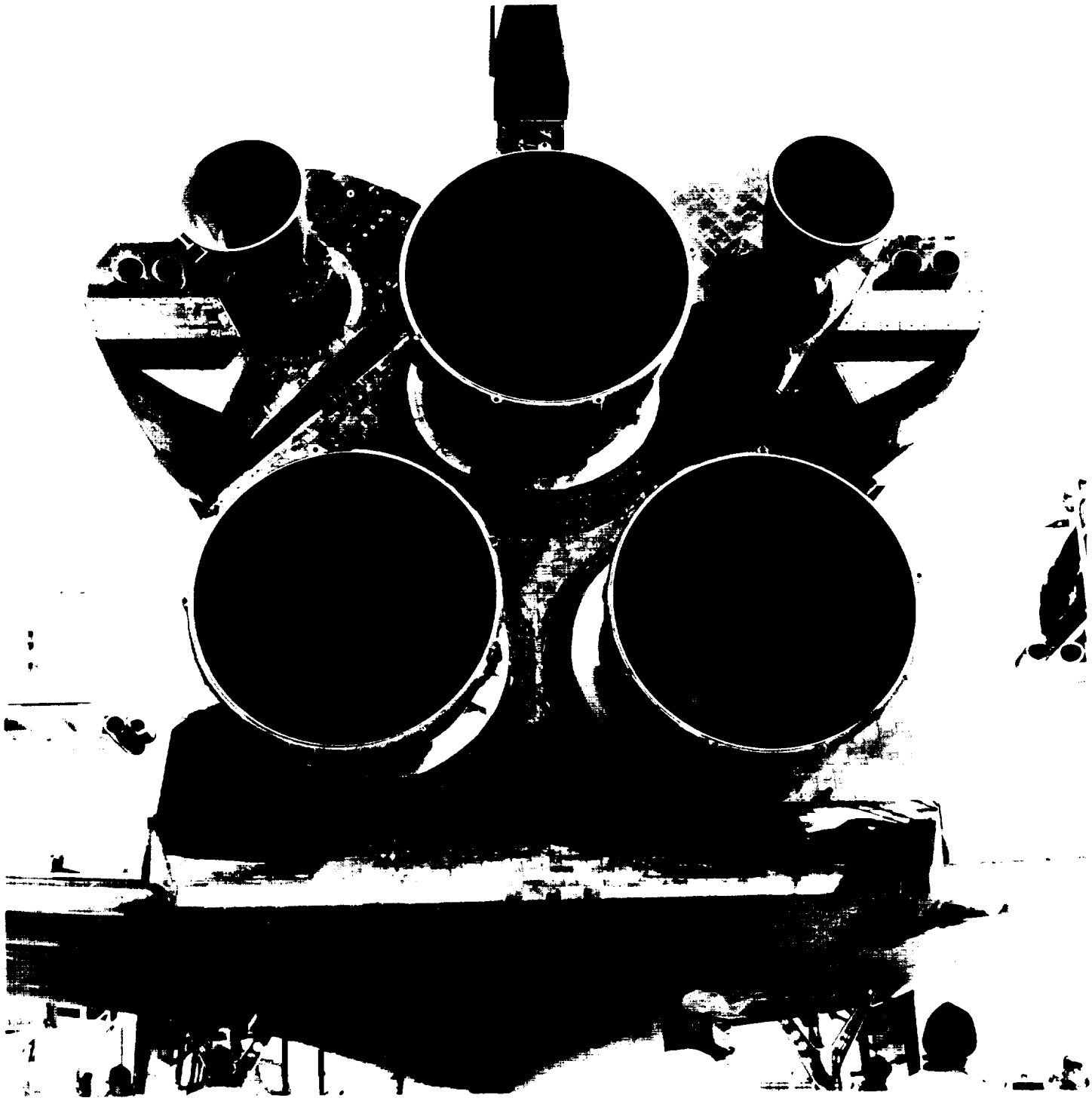


Photo 23: Base Heat Shield/SSME's

The SSME #1 and #2 Dome Mounted Heat Shield (DMHS) closeout blankets were unstitched or torn at the 6-7:00 o'clock and 3-5:00 o'clock locations, respectively. The SSME #3 DMHS was in excellent condition with no damaged material. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged.

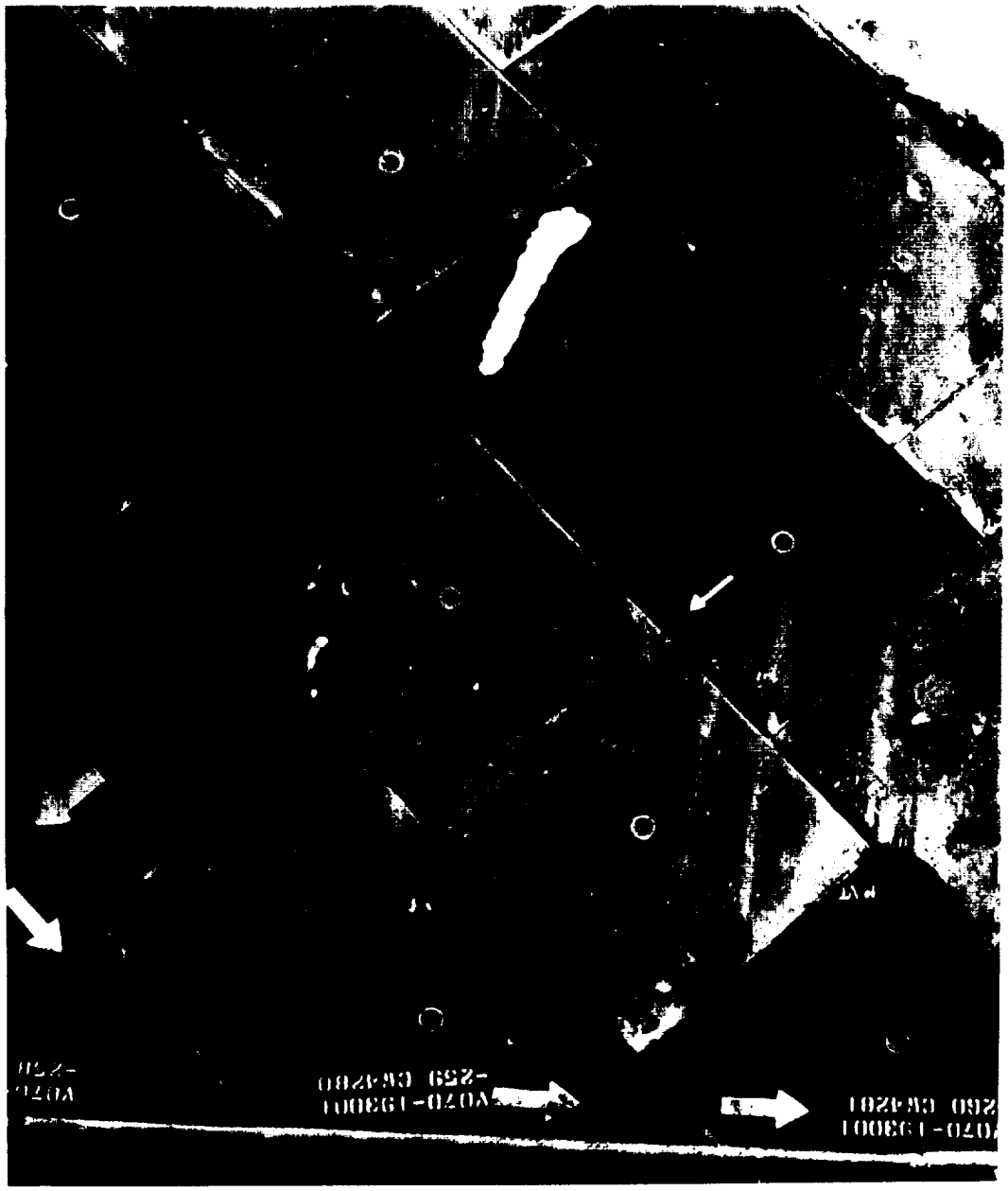


Photo 24: Lower Surface Tile Damage

The largest lower surface tile damage site occurred on the right inboard elevon and measured 5.0-inches long by 1.0-inches wide by 0.75-inch maximum depth. Hits on the right side along a line from nose to tail are generally attributed to ice impacts from the ET LO2 feedline bellows and support brackets.

Photo 25: LH2 ET/ORB Umbilical

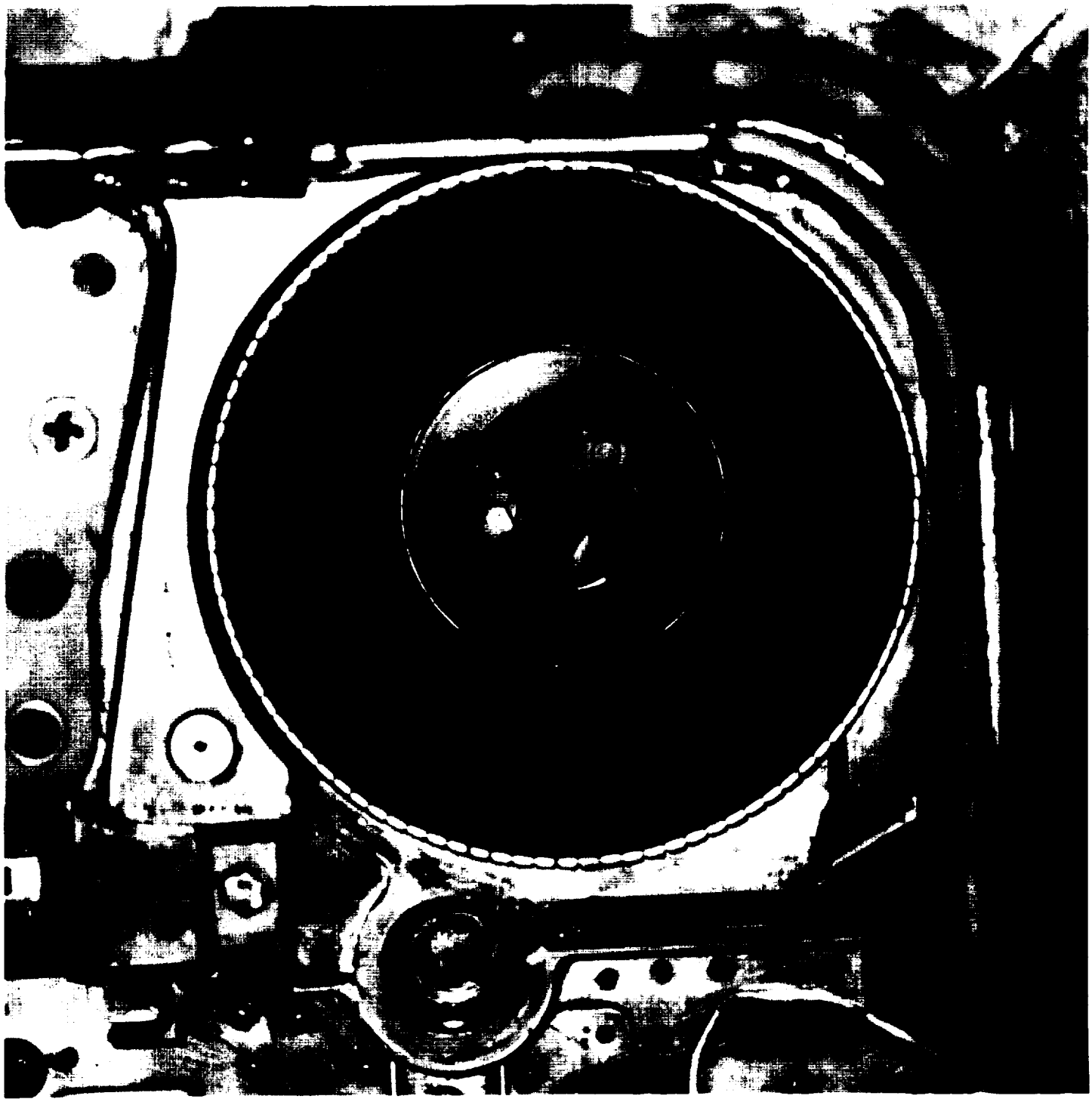


Photo 26: EO-2 Debris Container Iris

ET/Orbiter separation devices EO-1 and EO-3 functioned normally. The EO-2 debris container iris was obstructed and had not closed fully. No ordnance fragments were found on the runway beneath the umbilical cavities.

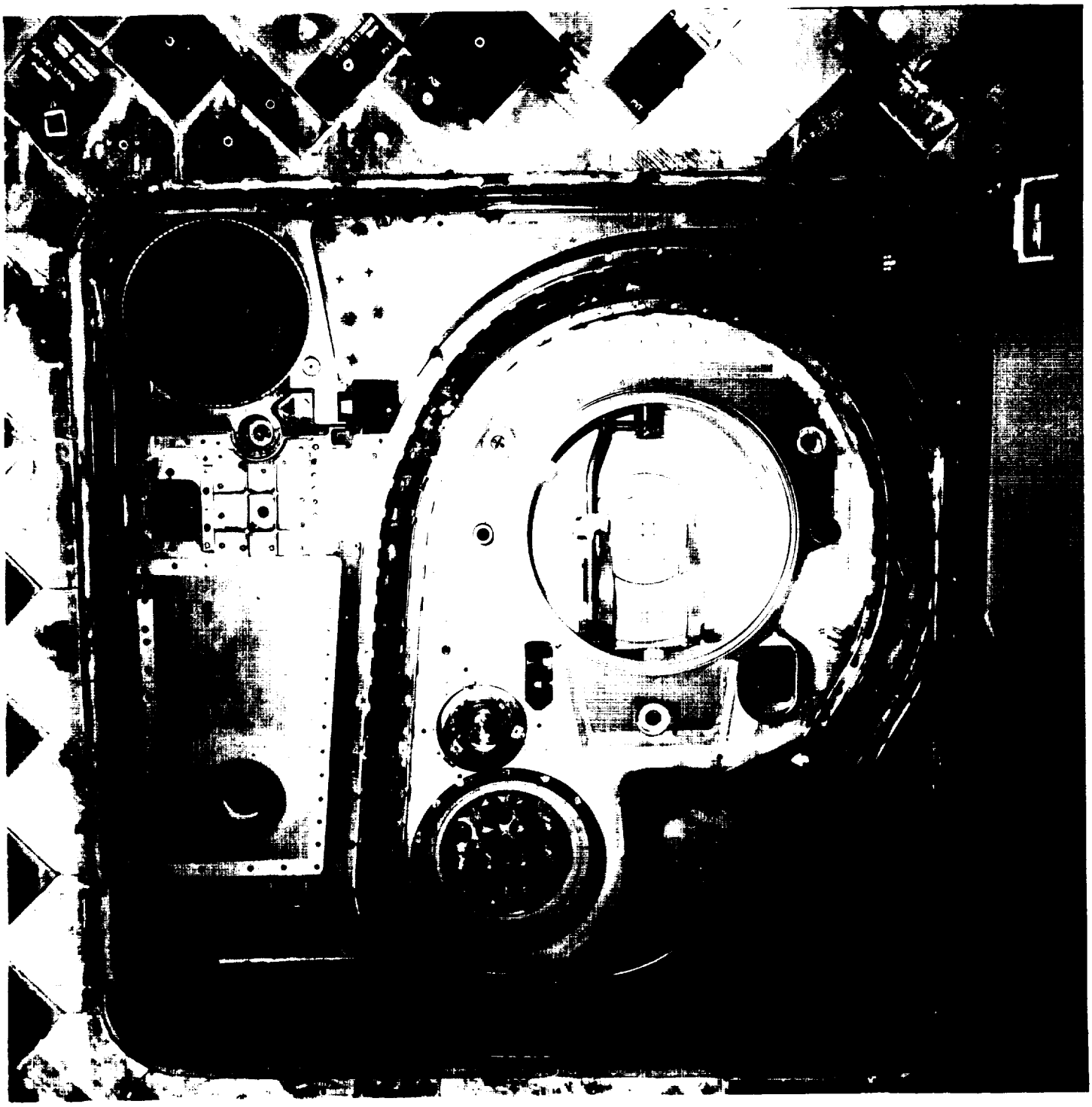


Photo 27: LO2 ET/ORB Umbilical

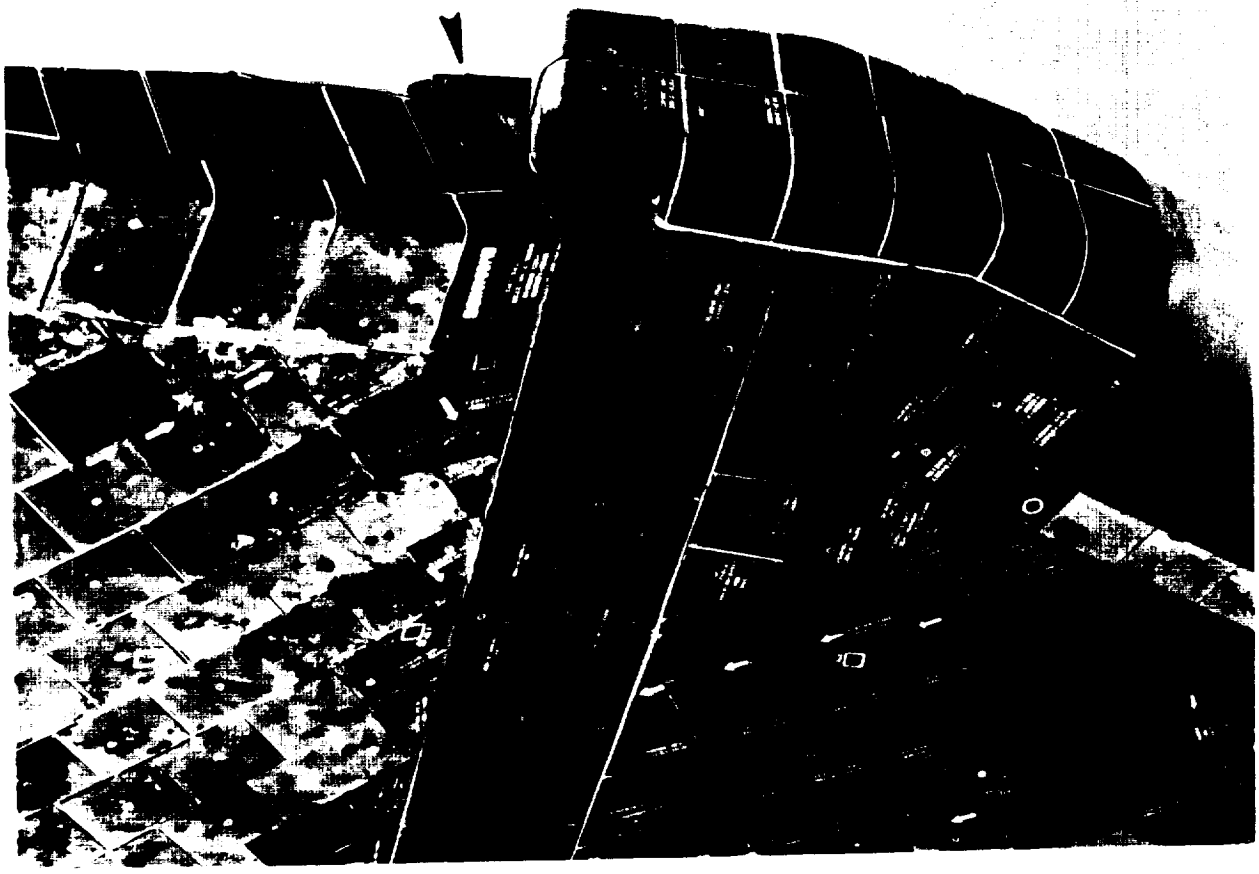


Photo 28: Flipper Door #15

Right outboard flipper door #15 was dislocated from the rail

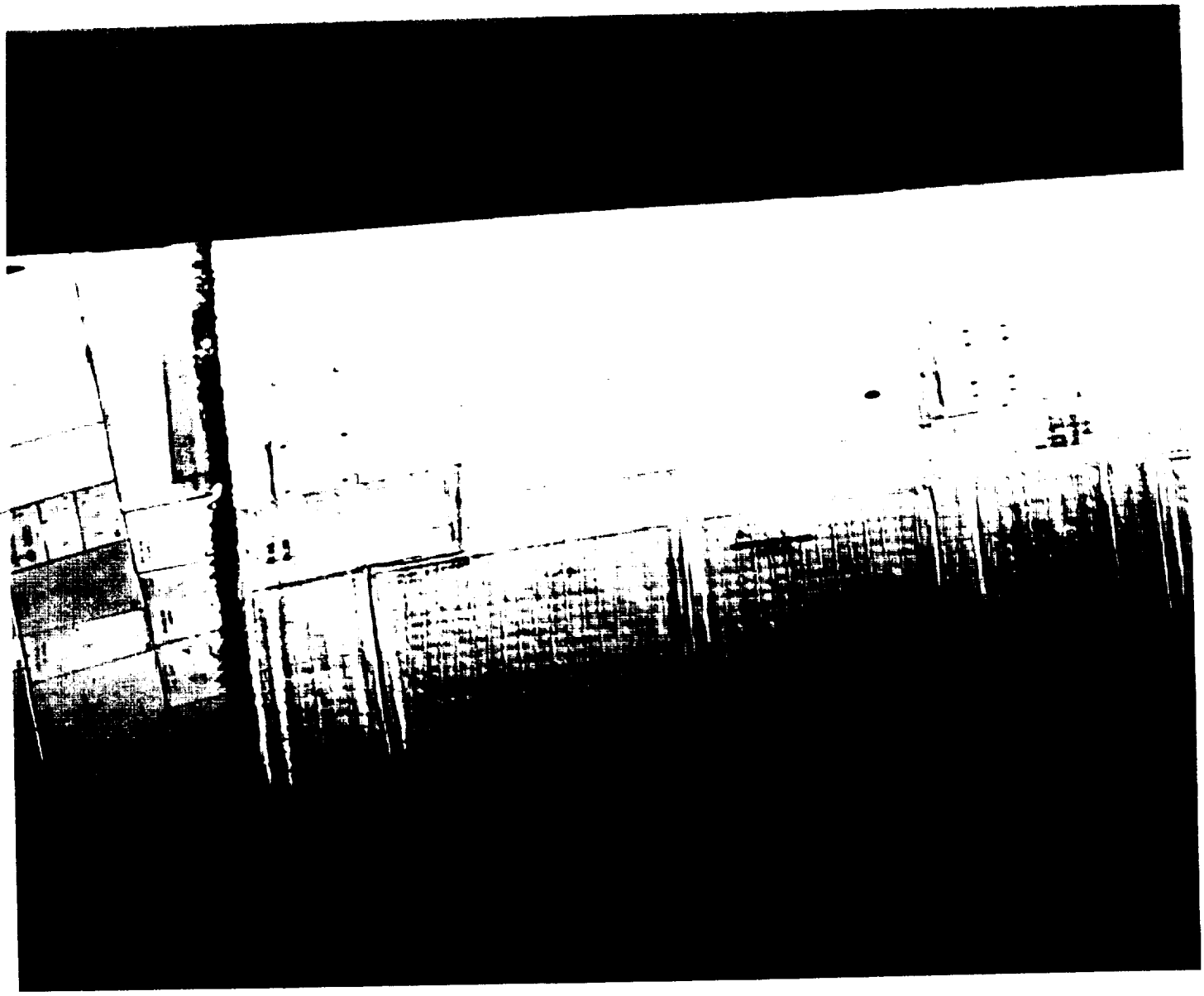


Photo 29: Payload Bay Door Discoloration

No ice adhered to the payload bay door. However, a reddish-brown discoloration similar to that observed previously on OV-105 was present on the leading edge of the LH payload bay door.

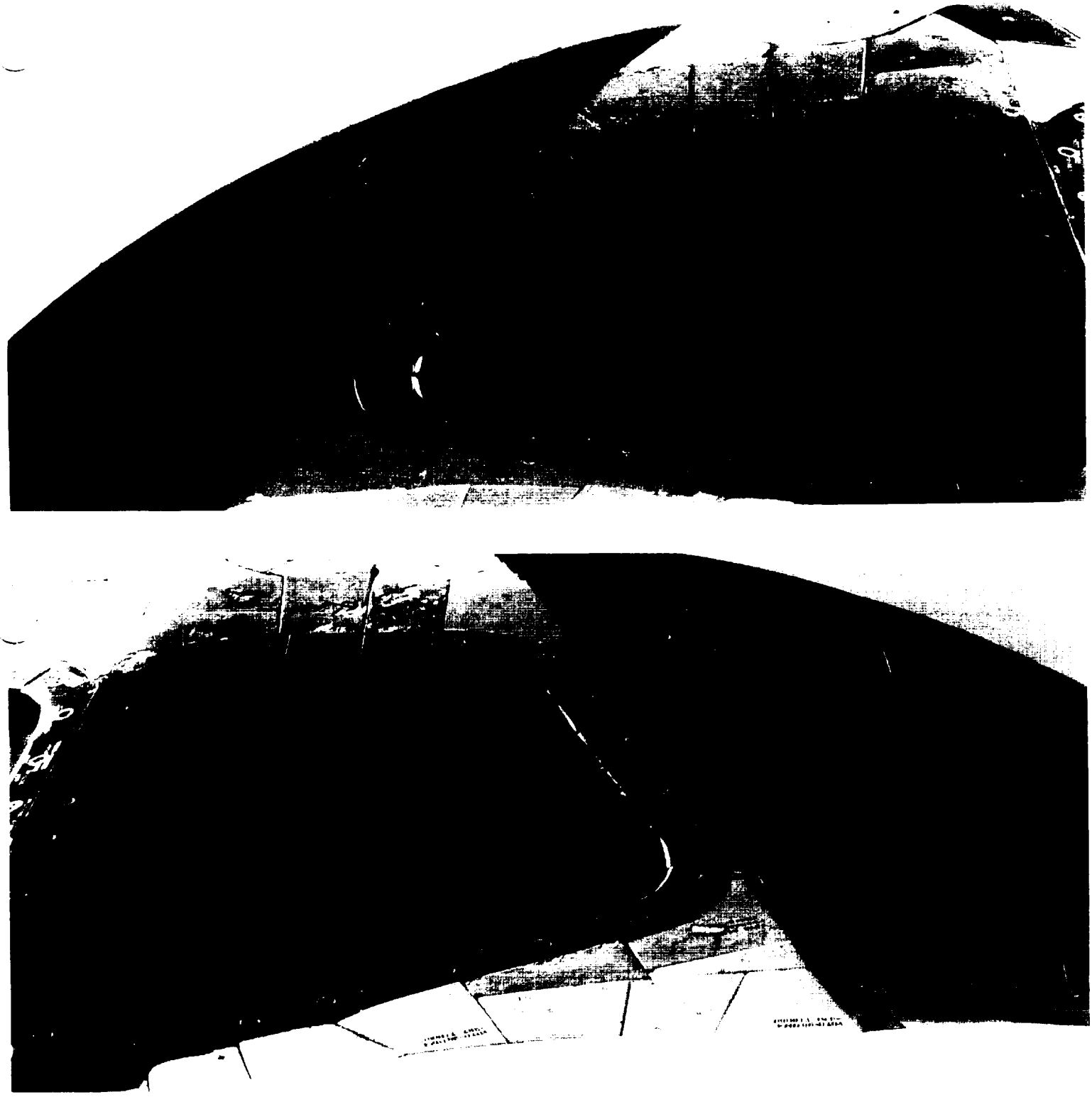


Photo 30: Orbiter Windows

Orbiter window hazing and streaking was typical. The numerous damage sites on the window perimeter tiles were attributed to a combination of new hits from FRCS thruster paper cover/adhesive and old tile repair material flaking off.

Photo 31: Runway Light Damage

All drag chute hardware was recovered and appeared to have functioned normally. The drag chute door had skidded along the runway and impacted a runway perimeter light. The major pieces of the light stanchion and lens were recovered.

8.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-102 Columbia during the STS-75 post landing debris assessment at Kennedy Space Center. The submitted samples consisted of 8 wipes from Orbiter windows #1-8. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

8.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to facility environment, SRB BSM exhaust (including metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile repair, and glass insulation), Orbiter window polish residue, building type insulation, paints and primer from various sources. There was no apparent vehicle damage related to these residuals.

8.2 ORGANIC ANALYSIS

The results of the STS-75 organic analysis are pending.

8.3 STS-72 PRELAUNCH ORGANIC ANALYSIS

The results of the recently-received STS-72 prelaunch organic sample analysis revealed the presence of RTV (RCS nozzle cover and ORB TPS), phenolic, isocyanurate foam and epoxy materials. These particulate types are common to STS processing. The precise sources are under assessment.

8.4 NEW FINDINGS

This set of post-flight debris residual samples provided added data to source information for STS debris sampling. The STS-72 prelaunch window and window cover samples organic analysis has shown the presence of polyamide in sample wipe. This material had previously been attributed to the window covers. The presence of phenolic and isocyanurate foam is also being evaluated as a new finding, although these material types are common to the STS environment. The variety of residual material continues to be representative of that documented in previous mission sampling (reference Figure 8 for STS-75).

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
75	Metallics - Fac.Env./BSM Residue(SRB) Tile repair (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics Window polish residue Paint and primer				
72	Metallics - Fac.Env./BSM Residue(SRB) RTV, Tile, Tile repair (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics Window polish residue Paint and primer				Pre-launch Window Cover: Metallic-Fac.Env.;RTV,Tile-(TPS) Insulation Glass - (ORB TPS) Earth Minerals; Organics--phenolic, urethane, isocyanurate foam Pre-launch Window: Metallic - Fac.Env.;Window polish res RTV,Tile,Tile repair,Ins glass (TPS); Earth Minerals,Paint/primer;Organics-phenolic,urethane,isocyanurate foam
74	Metallics - Fac.Env./BSM Residue(SRB) RTV (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics - Plastic polymers, sealant, RTV(RCS thruster nozzle cover adhesive) SRB sealant Paint and primer				
73	Metallics - Fac. Env./BSM Residue (SRB) Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Earth Minerals Organics - Plastic polymers, sealant, RTV(RCS thruster nozzle cover adhesive) Paint and primer				
69	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile filler (ORB TPS) Insulation glass (ORB TPS) Earth minerals Building type insulation Organics -RTV(RCS adhesive),Plastic polyme Orbiter window polish residue Paint and primer				

For data on previous missions refer to mission reports prior to STS-59

Figure 8: Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
70	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile filler (ORB TPS) Insulation glass (ORB TPS) Earth minerals Building type insulation Organics - RTV, Plastic polymers RTV - RCS thruster nozzle cover adhesive Paint and primer				
71	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Earth minerals (landing site) Organics - Plastic polymers RTV - RCS thruster nozzle cover adhesive Paint and primer				
67	Metallics - Fac. Env./BSM Residue (SRB) Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - sample cloth Earth minerals (landing site) Organics -RTV(RCS adhesive),Plastic polym Paint and primer				SRB sealant sample: laboratory reference
63	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile(ORB TPS) Hypalon paint (SRB)		
66	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
68	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		ET GOX Vent Seal land area and GOX Seal Sample - Metallic Particulate WINDOW DEBRIS SAMPLE - 'Butcher paper'

Figure 8 (continued): Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
64	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer				
65	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
59	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-Building insulation, wipe cloth Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV(RCS thruster nozzle cover adhesive) Paint and primer				

Sample locations vary per mission and not all locations are sampled for every mission.
( ) - identifies the most probable source for the material.
Metallics - includes mostly Aluminum and Carbon Steel alloys

For data on previous missions refer to mission reports prior to STS-59

Figure 8 (continued): Orbiter Post Landing Microchemical Sample Results

9.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 7 post launch anomalies, but no In-Flight Anomalies (IFA's), were observed on the STS-75 mission.

9.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. No items.

9.2 SOLID ROCKET BOOSTERS

1. A stud hang-up occurred on holddown post #5. As the vehicle gained altitude and the LH aft skirt cleared the stud, a semi-circular piece of aluminum from the stud hole wall fell onto the southwest corner of the HDP shoe and then downward into the haunch area. Two fragments that may have been aluminum shavings fell from the stud hole area.

9.3 EXTERNAL TANK

1. Four divots, ranging in size from 6 to 12-inches in diameter, were visible in the intertank-to-LH2 tank flange closeout (one in the -Y+Z quadrant; three in the +Y+Z quadrant near the EB fitting). In addition, a 5-inch diameter divot was observed in the LH2 tank acreage near the group of three divots in the flange closeout.

2. A thin, metallic object with straight edges (lightning contact strip) originated from the LH2 ET/ORB umbilical area shortly after umbilical separation and drifted in a general -Y-Z direction. Three other lightning contact strips from the LH2 umbilical appeared to be missing - a condition that could not be confirmed due to the sun angle/lighting conditions. Loss of lightning contact strips has been documented on previous IFA's.

9.4 ORBITER

1. A thin, flexible, 6-inch by 1-inch object, believed to be a GSE tile shim, first entered the field of view near the LH inboard elevon +Z side at 20:17:58.379 GMT. The object appeared to contact the aft fuselage sidewall near the body flap hinge area and the lower portion of the SSME #2 nozzle while falling aft. No resulting damage was visible. The GSE shim should have been removed before flight.

2. The EO-2 debris container iris was obstructed and had not closed fully.

3. Right outboard flipper door #15 was dislocated from the rail.

4. A reddish-brown discoloration was present on the leading edge of the LH payload bay door.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

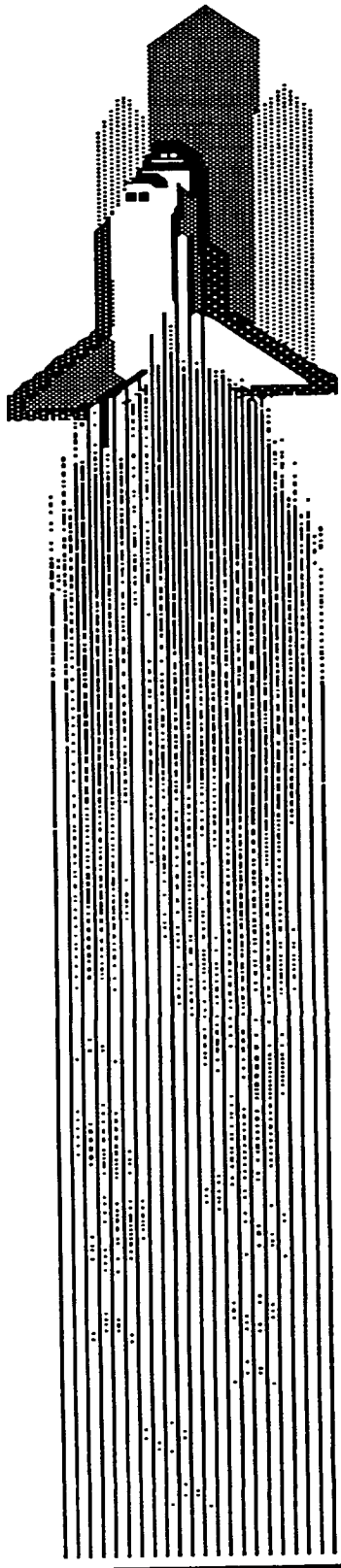
Space Shuttle

Earth Science Branch

Image Science and Analysis Group

STS-75 Summary of Significant Events

April 15, 1996



Space Shuttle Image Science and Analysis Group

STS-75 Summary of Significant Events

Project Work Order - SN-5CR

Approved By

Lockheed Martin

Robert Meltzer, Project Analyst
Image Science and Analysis Group

M. H. Trenchard, Project Manager
Image Analysis Projects

Jess G. Carnes, Operations Manager
Basic and Applied Research Department

NASA

Diane McLaughlin, Lead
Image Science and Analysis Group
Earth Science Branch

Prepared By

Lockheed Martin Engineering and Sciences Company
for
Earth Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

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1. STS-75 (OV-102): FILM / VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-75 launch of Columbia (OV-102) from pad B occurred on Thursday, February 22, 1996, (day 053) at 20:18:00.013 Coordinated Universal Time (UTC) as seen on camera E9. Solid Rocket Booster (SRB) separation occurred at 20:20:06.309 UTC as seen on camera ET212.

On launch day 24 of 24 expected videos were received and screened. Following launch day, 53 films were screened. No potential anomalies were observed during launch.

Detailed Test Objective 312, photography of the external tank after separation, was performed using the Orbiter umbilical well cameras (method 1) and handheld photography of the external tank using the Nikon F4 with the 400 mm lens plus 2X converter.

1.1.2 Landing

Columbia landed on runway 33 at KSC on March 9, 1996. Twelve videos and eleven films of the Orbiter's approach and landing were received.

No major anomalies were noted in any of the approach, landing, or roll-out video views screened. The drag chute deployment appeared normal.

1.2 TIMING ACTIVITIES

Launch:

The time codes from videos and films were used to identify specific events during the initial screening process.

Video cameras: ET204, ET 207, ET208, ET212, ET213, KTV2, KTV5, KTV13, KTV4B, KTV7B, KTV21B, KTV11B, OTV150, had IRIG timing.

Film cameras: E31, E41, E204, E205, E207, E208, E212, E213, E218, E220, and E223 had IRIG timing. E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E20, E25, E26, E30, E33, E34, E35, E36, E40, E50, E52, E54, E57, E59, E60, E62, E63, E65, E76, E77, E79, and E222 had in-frame alphanumeric timing.

Landing:

Video cameras: Twelve videos were screened on landing day. Eight videos: KTV5L, KTV6L, KTV11L, KTV12L, KTV13L, KTV15L, KTV20L, KTV33L, and EL17 IR had IRIG timing. There was no IRIG timing for videos EL18, SLF South, SLF North.

Film cameras: Film cameras EL1, EL2, EL4, EL7, EL8, EL9, EL10, EL12, EL15, EL30, and EL31 had in-frame alphanumeric timing.

The landing and drag chute event times are provided in Table 1.2.

Event Description	Time (UTC)	Camera
Landing Gear - Doors Opened	069:13:58:01.314	KTV12L
Right Main Wheel Touchdown	069:13:58:20.213	EL17 IR
Left Main Wheel Touchdown	069:13:58:20.313	EL17 IR
Drag Chute Initiation	069:13:58:28.112	KTV6L
Pilot Chute at Full Inflation	069:13:58:29.013	KTV6L
Bag Release	069:13:58:29.689	KTV6L
Drag Chute Inflation in Reefed Configuration	069:13:58:30.547	KTV6L
Drag Chute Inflation in Disreefed Configuration	069:13:58:33.774	KTV33L
Nose Wheel Touchdown	069:13:58:35.462	EL17 IR
Drag Chute Release	069:13:58:51.802	KTV6L
Wheel stop	069:13:59:23.156	KTV33L

Table 1.2 Landing Video Timing Events

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS

2.1.1 Debris Near the Time of SSME Ignition

As on previous missions, multiple pieces of debris were seen near the time of SSME ignition. Most of the debris was umbilical ice and RCS paper. No follow-up action was requested.

2.1.1.1 Debris Aft of Body Flap
(Camera: OTV163)

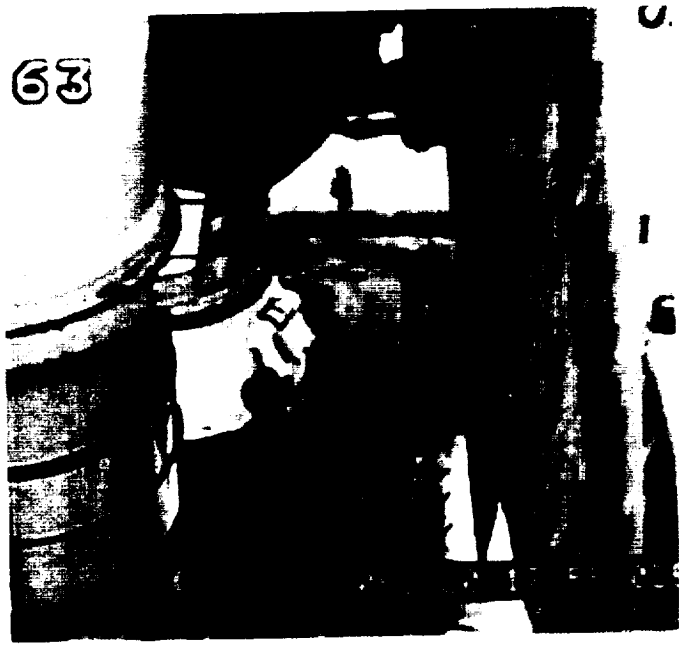

Figure 2.1.1.1 Debris Aft of Body Flap

A single piece of light colored debris (possible flame duct debris) was seen aft of the body flap prior to liftoff (53:20:17:55.055 UTC). The debris was not seen to contact the vehicle.

2.1.1.2 Debris Strikes LH2 Umbilical Door Sill
(Camera: OTV109)

A single light colored piece of debris (probable ice debris) hit the LH2 umbilical door sill at SSME ignition (053:20:17:57.056 UTC). No damage to the vehicle was noted.

2.1.1.3 Debris Near LSRB

(Cameras: E30)

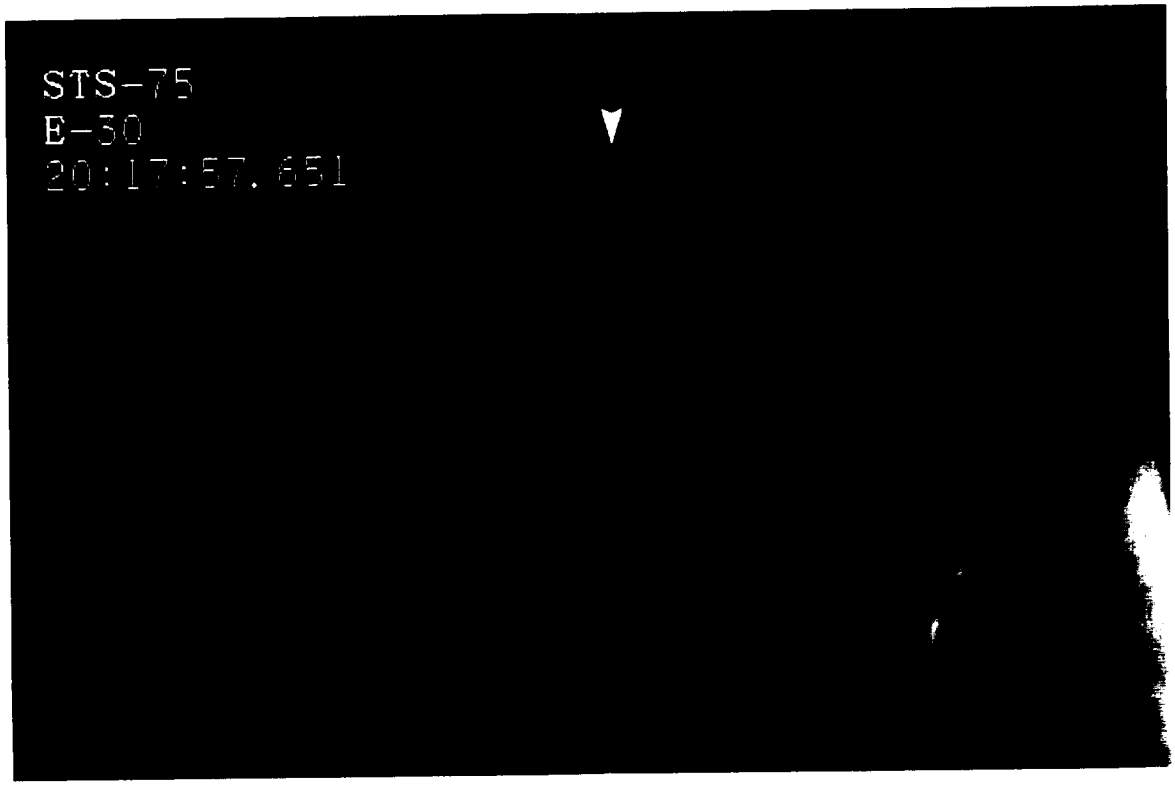

Figure 2.1.1.2 Debris Near LSRB

A small dark piece of debris fell between the camera and the LSRB prior to liftoff (20:17:57.651 UTC). The debris was not seen to contact the vehicle.

2.1.1.4 Rectangular Shaped Debris Strikes Orbiter
(Cameras: E18)

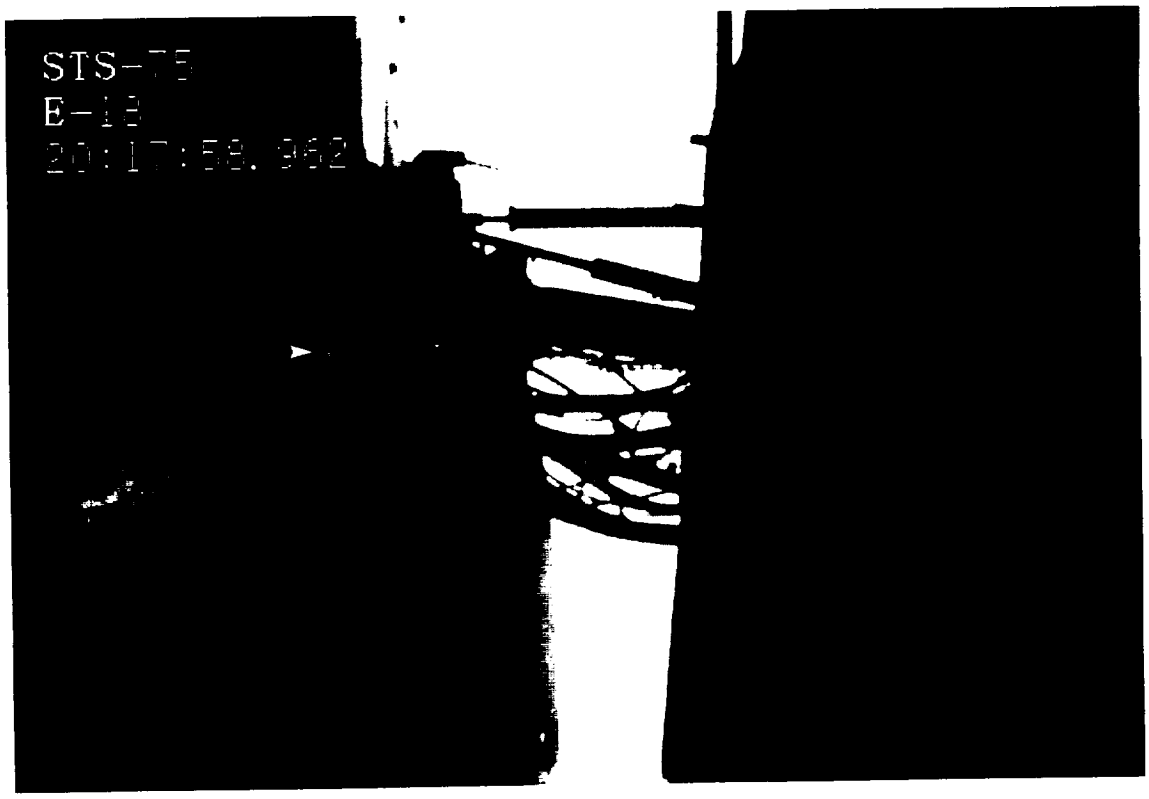

Figure 2.1.1.3 Debris Strikes Orbiter

A thin, rectangular shaped, light colored piece of debris (possible tile gap filler) fell from the top of the view and struck the Orbiter forward of the LH2 TSM T-0 umbilical, and then struck the exterior of the SSME #2 engine bell just prior to liftoff (17:58.962 UTC). No damage to the launch vehicle was visible.

2.1.2 Debris Near the Time of SRB Ignition

As on previous missions, multiple pieces of debris were seen near the time of SRB ignition. No follow-up action was requested.

2.1.2.1 Bolt Hang-Up on the LSRB Holddown Post M-5
(Camera: E12)

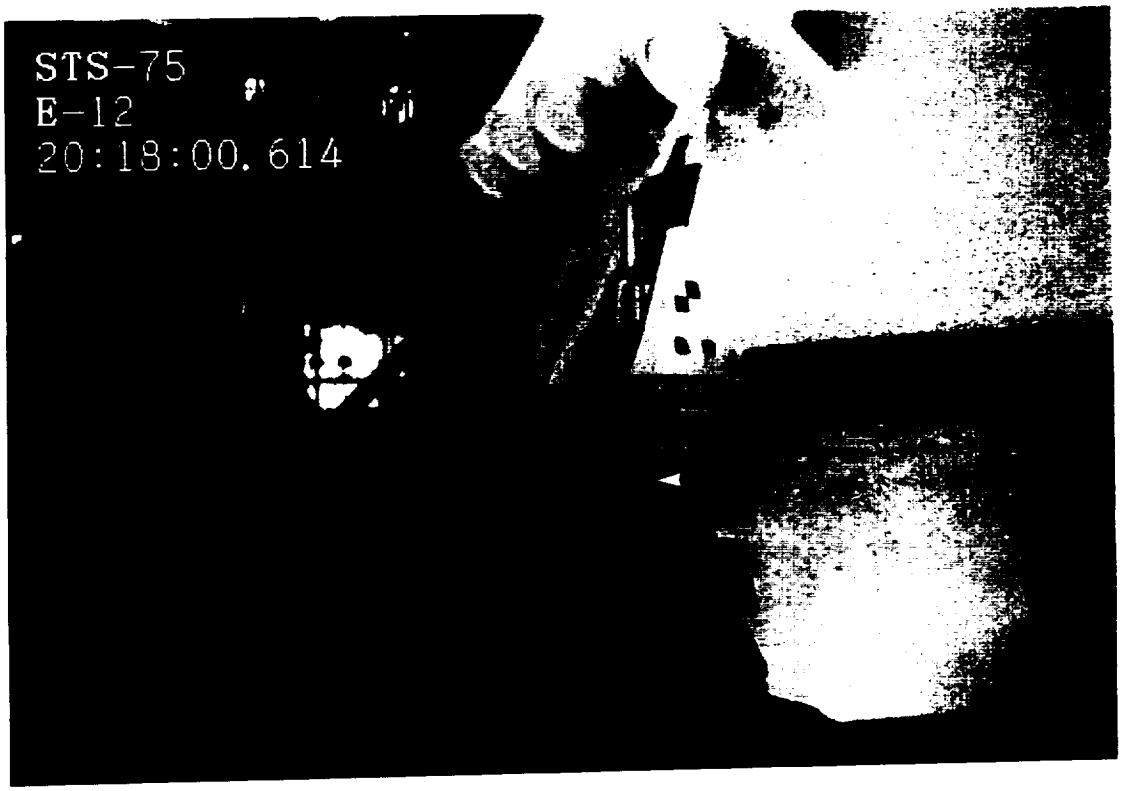

Figure 2.1.2.1 (A) Holddown Post Bolt Hang-Up

A bolt hang-up occurred on the LSRB holddown post M-5 at liftoff. Slight holddown post shoe movement was visible prior to the bolt release. A single piece of dark debris (possible frangible nut material) was seen coming from the Debris Containment System (DCS) area after the bolt release. The debris did not appear to strike the vehicle.

2.1.2.2 Metallic Debris Seen Near M-5 Holddown Post
(Camera: E12)

Figure 2.1.2.2 (B) Metallic Debris Near Holddown Post M-5

During M-5 bolt release a long, thin, piece of metallic debris was seen coming from the SRB bolt cavity. The debris struck the holddown post shoe and then fell down into the haunch area. No follow-up action was requested.

MISSION	LOCATION OF HANG-UP
STS-34	RSRB holddown post M-2
STS-33	RSRB holddown post M-3
STS-39	RSRB holddown post M-1
STS-43	LSRB holddown post M-7
STS-45	RSRB holddown post M-4
STS-50	RSRB holddown post M-4
STS-46	LSRB holddown post M-7
STS-53	RSRB holddown post M-1
STS-73	RSRB holddown post M-2

Table 2.1.2.2 SRB Holddown Post Bolt Hang-Ups Seen on Previous Missions

2.1.2.3 Thermal Curtain Tape Seen Near RSRB
(Camera: E7)

A loose thermal curtain tape was seen on the RSRB aft skirt near holddown post M-4 at liftoff. Loose thermal curtain tape has been seen on previous missions. No follow-up action was requested.

2.1.2.4 Flame Trench Debris
(Camera: E57)

Several pieces of light colored debris were seen coming from the SRB flame trench area at liftoff (20:18:02.293 UTC). The debris tracked in a northerly direction and did not contact the vehicle.

2.1.2.5 Debris from ET/RSRB Aft Attach Bottom Strut
(Cameras: E50, E60, E57)

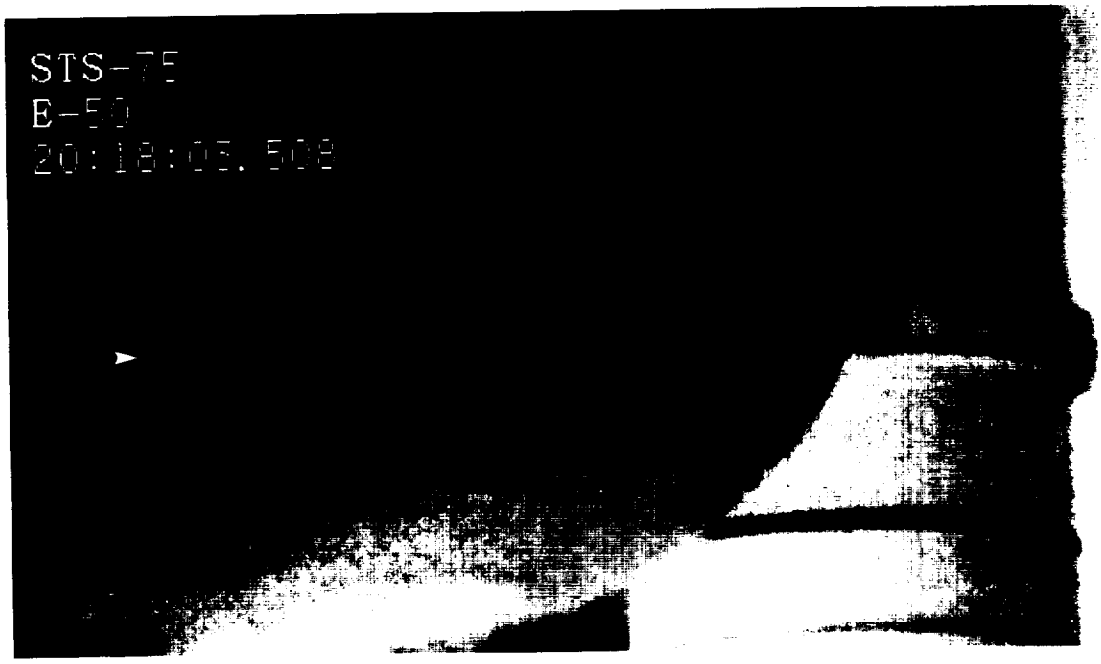

Figure 2.1.2.5 Debris from ET/RSRB Aft Attach

A single white colored piece of debris fell from the ET end of the ET/RSRB aft attach bottom strut during liftoff (20:18:03.266 UTC). The debris did not strike the vehicle.

2.1.2.6 Debris Strikes Tile Surface
(Camera: E52)

Several pieces of ice debris from the ET/Orbiter umbilicals struck the Orbiter lower tile surface forward of the body flap during liftoff (20:18:04.334 UTC). Also a single piece of ice debris from the ET/Orbiter umbilicals struck the lower body flap tiles at tower clear (20:18:05.377 UTC). No damage to the tiles was observed.

2.1.2.7 LH2 and LO2 Tail Service Mast (TSM) T-0 Umbilical Disconnect Debris
(Cameras: OTV109, OTV149, OTV150, OTV151, OTV163, OTV170, OTV171, E17, E18, E19, E20, E76, E77)

Normal ice debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at liftoff. None of the debris was observed to strike the vehicle.

2.1.2.8 GH2 Vent Arm Debris During Disconnect and Retraction
(Cameras: E33, E34, E35, E41, E50, E54)

Vapor and multiple light colored pieces of ice debris fell from the GH2 vent arm carrier plate at vent arm retraction. The GH2 vent arm appeared to retract normally.

2.1.3 Debris After Liftoff
(Camera: E40, E52, E57, E59, E213, E220, E222, E223)

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) after liftoff on the launch tracking views. The debris was probably reaction control system (RCS) paper and ice from the ET/Orbiter umbilicals. None of the debris was seen to contact the launch vehicle. No follow-up action was requested.

2.1.3.1 Debris in Exhaust Cloud
(Cameras: E4, E77)

Rope like debris (possible water baffle material) was seen in the exhaust cloud after liftoff (20:18:03.852 UTC).

2.1.3.2 Debris In SSME Exhaust Plume
(Camera: E52, E57, E220, E222, E223)

E213, E222 - Multiple light colored pieces of debris (probably umbilical ice and RCS paper) were seen falling aft of the vehicle after the roll maneuver (20:18:17.4 - 20:18:39 UTC). Examples include (1) a single orange colored piece of debris between the SRB nozzles (20:18:14 UTC) (this debris may have been a piece of umbilical purge barrier material, (2) a single light colored piece of debris falling over the right Orbiter wing (20:18:24.6 UTC), (3) a single light colored piece of debris near the body flap (20:18:39.3 UTC).

2.2 MOBILE LAUNCH PLATFORM (MLP) EVENTS

2.2.1 Tile Surface Erosion
(Cameras: E17, E18, E20)

Small areas of tile surface coating erosion were noted on the base of the left RCS stinger, on the base of the right OMS pod, and on the base heat shield near SSME # 2 and #3 during SSME ignition. tile surface erosion has been seen on previous missions. No follow-up action was requested.

2.2.2 Orange Vapor
(Cameras: OTV170, OTV171)

Figure 2.2.2 Orange Vapor

Orange vapor (possible free burning hydrogen) was seen above the rim of SSME #1 prior to liftoff. Orange vapor has been seen on previous missions. No follow-up action was requested.

2.2.3 SSME Mach Diamond Formation
(Cameras: OTV151, OTV170, OTV171)

The SSME Mach Diamonds formed in the normal sequence. The times of the Mach Diamond sequence were:

SSME #3 - 053:20:17:56.690 UTC
SSME #2 - 053:20:17:56.890 UTC
SSME #1 - 053:20:17:57.023 UTC

2.3 ASCENT EVENTS

2.3.1 Flares in SSME Exhaust Plume

(Cameras: KTV4B, KTV21B, ET207, ET212, E2, E31, E207, E222)

Figure 2.3.1 Flares in SSME Exhaust Plume

Several flares were seen in the SSME exhaust plume from liftoff until after the roll maneuver (20:18:00.654 - 20:18:38.677 UTC). Flares in the SSME exhaust plume have been seen on previous missions. No follow-up action was requested.

2.4 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

2.4.1 Analysis of Handheld Photography of the ET (Task #3)

One roll of STS-72 handheld photography was taken using the Nikon F4 with the 400 mm lens plus 2X extender. This is the first time the 400 mm lens has been used for DTO-312. Also, to compensate for no DTO-312 pitch maneuver an early OMS-2 pitch was performed to bring the external tank into view earlier than would have otherwise been the case. Five usable frames were acquired for analysis.

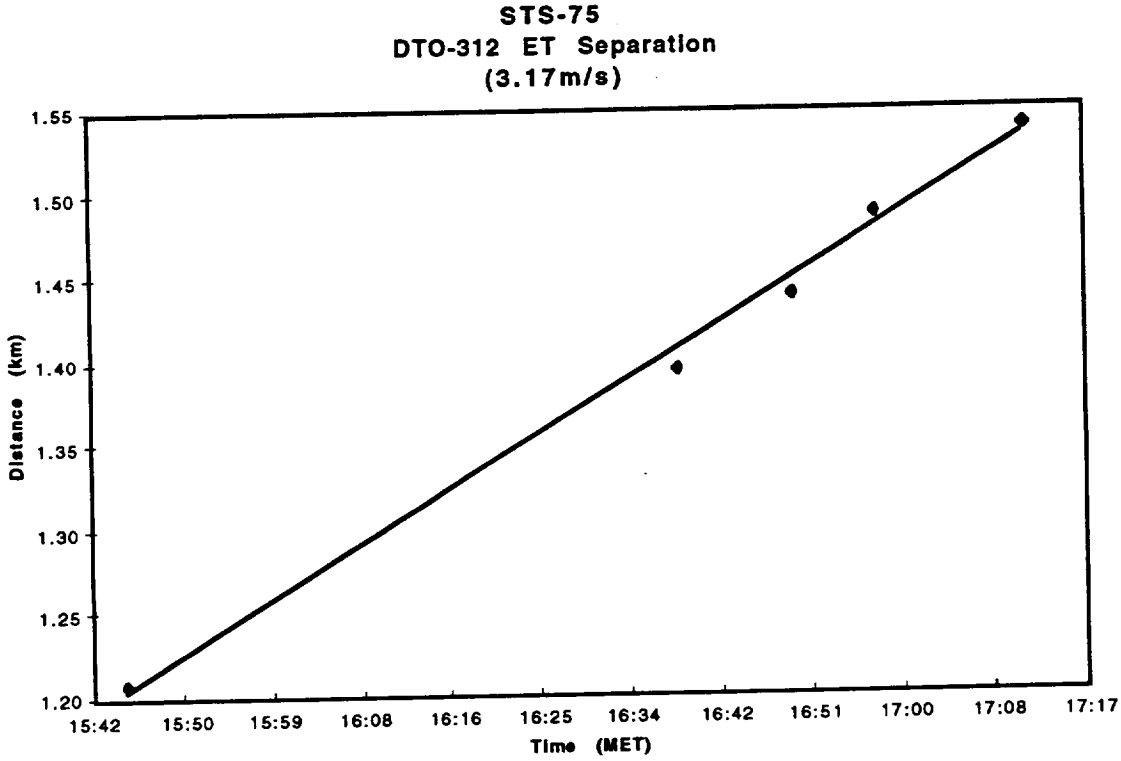

Figure 2.4.1 (A) ET Separation Velocity

Using the 35 mm handheld (Nikon F4) camera film, the external tank distance was calculated over a 5 frame sequence. The external tank was calculated to be a distance of 1.21km away from the Orbiter at 15:45 MET; 86 seconds later at 17:11 MET the tank was calculated to be at a distance of 1.54km. The tank separation velocity was determined to be 3.17 m/s. Roll rate was estimated at 0.1°/sec, and tumble rate was estimated at 0.03°/sec. The separation velocity and roll/tumble rates were similar to previous mission measurements.

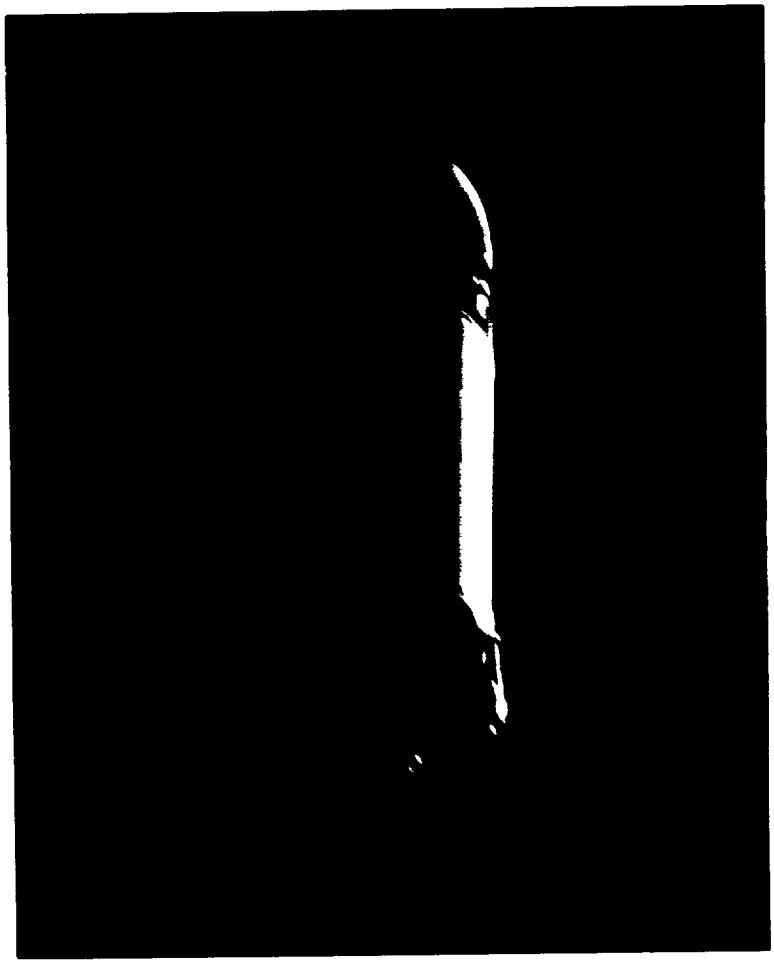

Figure 2.4.1 (B) 35 mm Handheld (Nikon F4) External Tank Photography (DTO-312)

Burn scars are apparent near the SRB attach points (1). RSRB separation burn scars have been seen on previous missions and are not considered anomalous.

2.4.2 Analysis of the Umbilical Well Camera Films (Task #2)

Three rolls of STS-76 umbilical well camera film were acquired: the 16 mm film (5 mm lens), and the 16 mm film (10 mm lens) from the LH2 umbilical, and the 35 mm film from the LO2 umbilical. Neither the +X translation nor pitch maneuvers were performed on STS-76.

As on previous missions, multiple pieces of debris was seen throughout SRB separation. Most of the debris was TPS insulation. No follow-up action was requested.

Figure 2.4.2 Possible Lightning Contact Strip (5 mm Camera View)

A metallic looking piece of rectangular shaped debris (possible lightning contact strip) first appeared after ET/Orbiter purge between the ET and ET/Orbiter electrical tray near the LH2 umbilical, the debris moved in a -Y direction away from the vehicle. The debris did not appear to strike the vehicle. No follow-up action was requested.

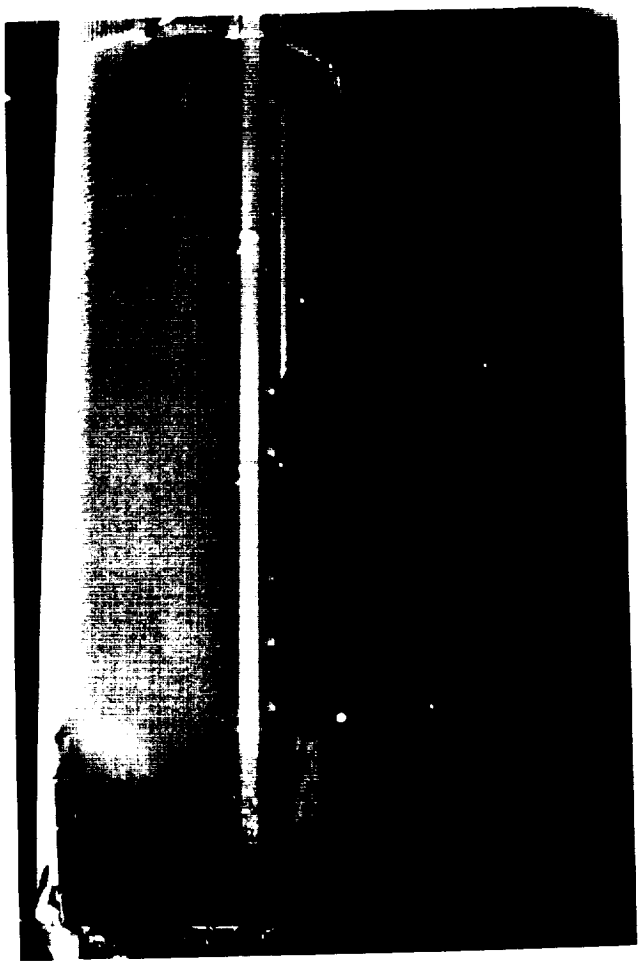

Figure 2.4.3 Debris Strikes LSRB (35 mm Camera View)

Several small divots were seen to the right of the forward attach bipod on the +Y side of the ET intertank/LH2 tank flange. Divots on the ET has been seen on previous missions. No follow-up action was requested.

2.5 LANDING EVENTS

2.5.1 Landing Sink Rate Analysis (Task #3)

The main gear sink rate of the Orbiter was determined over a one second time period prior to main gear touchdown using landing film. Nose gear sink rate was determined over a one second time period prior to nose gear touchdown using landing film

The measured main gear values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-75 Orbiter was reported to be 228,500 lb.). The sink rate measurements for STS-75 are given in Table 2.5.1. In Figure 2.5.1 the trend of the measured data points for film image data are illustrated.

Prior to Touchdown (1 Second)	Sink Rate: Film
Main Gear	0.8 ft/sec
Nose Gear	4.6 ft/sec

Table 2.5.1 Sink Rate Measurements

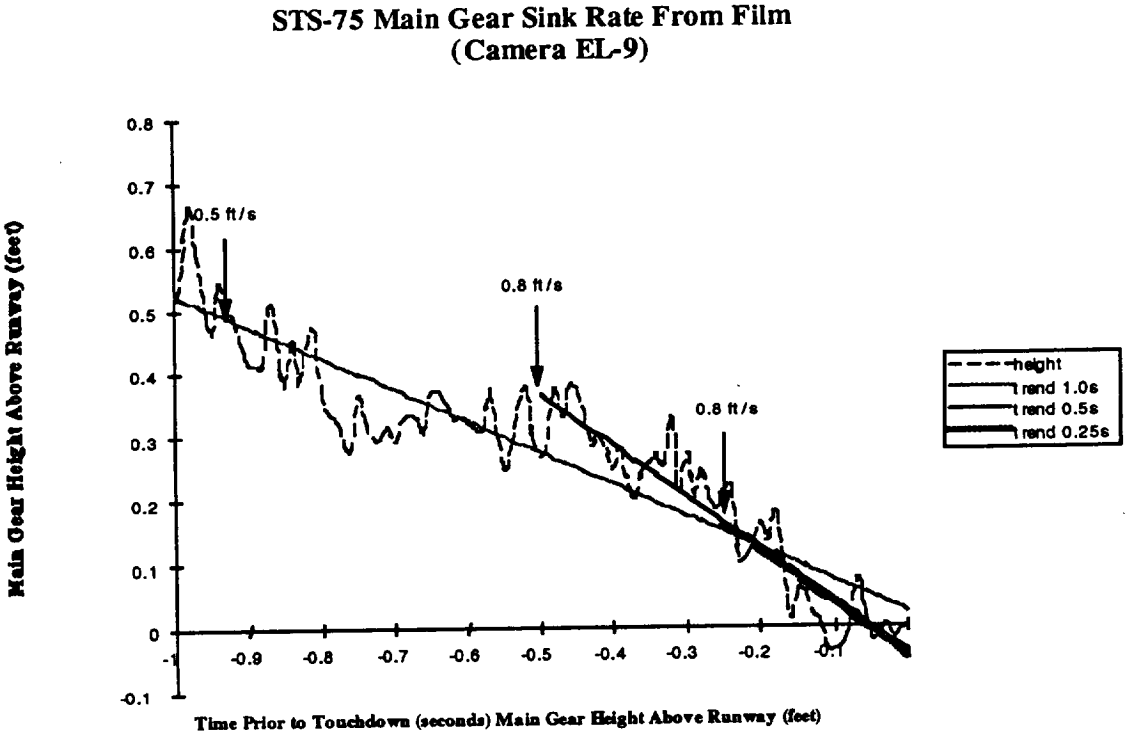

Figure 2.5.1 Main Gear Height Versus Time Prior to Touchdown (Film)

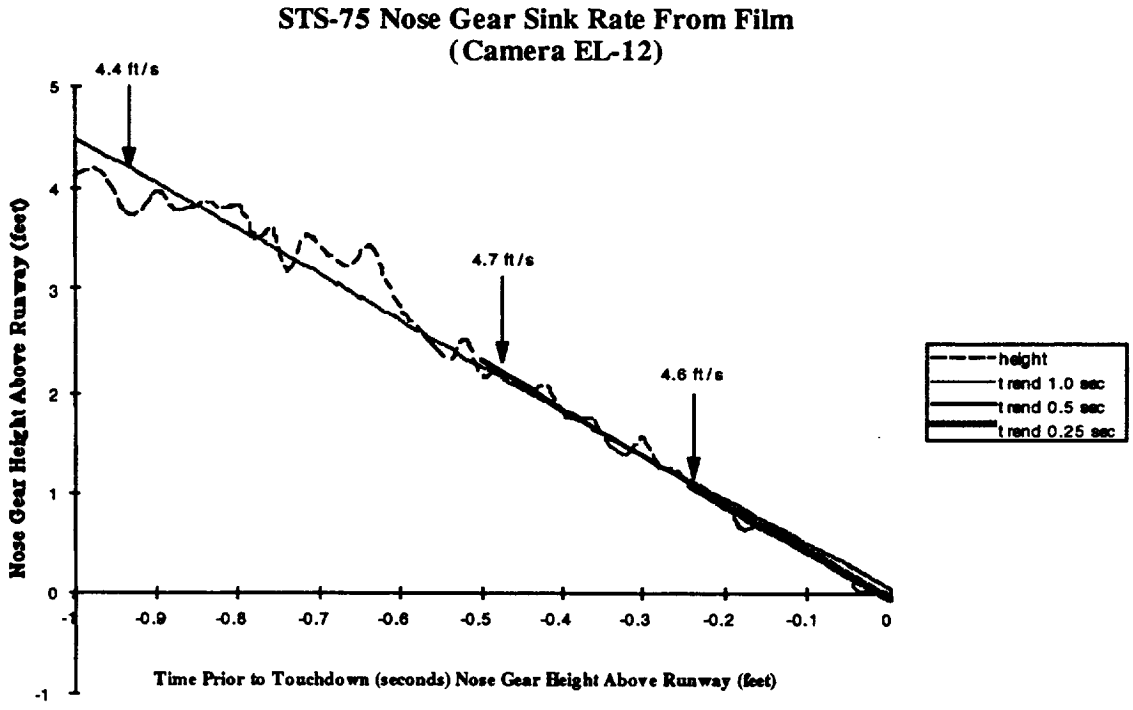

Figure 2.5.2 Nose Gear Height Versus Time Prior to Touchdown (Film)

2.6 OTHER

2.6.1 Normal Events

Other normal events observed include: Vapor from the ET vent louver, inboard elevon motion at SSME ignition, flares in SSME exhaust at SSME ignition, RCS paper debris at SSME ignition through liftoff, vapor and ice from the TSM T-0 disconnect areas during liftoff, ice and vapor from the ET/Orbiter umbilicals from SSME ignition through liftoff, ET twang, acoustic waves at liftoff, pad debris during SSME ignition through liftoff, flame duct debris at liftoff, debris in the exhaust cloud after liftoff, vapor off the SRB stiffener rings after liftoff, outgassing of the ET aft dome, charring of the ET aft dome, roll maneuver, forward RCS paper detaching after the roll maneuver, slight body flap motion, expansion waves after the roll maneuver, Condensation around the launch vehicle, SRB plume brightening prior to SRB separation, linear optical effects, SRB separation.

Normal events seen that are related to the pad are hydrogen ignitor operation, fixed service structure (FSS) deluge water activation, GH2 vent arm retraction, sound suppression water initiation, mobile launch platform (MLP) water dump activation, LH2 and LO2 TSM T-0 umbilical disconnect, TSM door closure at liftoff.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Reply to Attn of: EP42 (96-14)

March 21, 1996

TO: Distribution

FROM: EP42/Thomas J. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-75

The launch of space shuttle mission STS-75, the nineteenth flight of the Orbiter Columbia occurred on February 22, 1996, at approximately 2:18 P.M. Central Standard Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Photographic and video coverage was evaluated to determine proper operation of the MSFC related flight hardware.

Film was received from fifty-four requested cameras as well as video from twenty-four requested cameras. All ground based cameras appeared to operate properly. Long-range tracking camera coverage was degraded due to the high atmospheric moisture content.

The astronauts recorded seven images of the ET after separation using a hand-held 35mm camera The -Z side of the tank was imaged. Backlighting of the tank provided reduced data. The 35mm camera in the LO2 umbilical-well imaged up to the intertank region since no +X translation was performed.

The following observations were made. The typical events of ice/frost falling from the 17" disconnects at SSME ignition and liftoff, butcher paper falling from the vehicle and debris induced streaks were noted.

A holddown post stud hang-up was observed at post M-5 at liftoff. The stud appeared to remain fully extended until becoming free of the aft skirt.

Two streaks were observed in the plume of SSME #1 during liftoff at 20:18:00.645 and 20:18:01.016 UTC. These streaks appeared to be attached to the exit plane of the nozzle indicating internal sources.

A small thin piece of debris of unknown origin was observed falling through the field-of-view of camera E-18.

Several flashes were observed in the SSME plumes during ascent. These flashes are believed to be a result of debris entrainment.

The 35mm LO2 umbilical-well camera recorded three divots at the LH2 tank/intertank scarf joint near the -Y axis and one divot at the scarf joint near the +Y axis.

The following event times were acquired.

EVENT	TIME (UTC)	DATA SOURCE
M-1 PIC Firing	20:18:00.012	Camera E-9
M-2 PIC Firing	20:18:00.013	Camera E-8
M-5 PIC Firing	20:18:00.014	Camera E-12
M-6 PIC Firing	20:18:00.014	Camera E-13
SRB separation	20:20:06.33	Camera E-208

This report and additional information are available on the World Wide Web at URL:

http://photo4.msfc.nasa.gov/STS/sts75/sts75.html.

For further information concerning this report contact Tom Rieckhoff at 544-7677 or Jeff Hixson, Rockwell at 971-3082.

Thomas J. Rieckhoff

Enclosure

REPORT DOCUMENTATION PAGE

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John F. Kennedy Space Center, NASA
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ET/SRB Branch TV-MSD-7
Kennedy Space Center, Florida 32899

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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-75. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs and infrared scanner data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-75 and the resulting effect on the Space Shuttle Program.

14. SUBJECT TERMS

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EE31/M. A. Pessin
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Rockwell - Downey

Rockwell International
12214 Lakewood Blvd
Downey, CA 90241

AE21/J. McClymonds
FA44/R. Ramon

Martin Marietta

13800 Old Gentilly Road
New Orleans, Louisiana 70129

Dept. 3571/S. Copsey
Dept. 4200/P. Lewis

P. O. Box 29304
New Orleans, Louisiana 70189